0053485

BHI-01293
Rev. 0

Data Quality Objectives Summary Report for the 100-NR-1 Treatment, Storage, and Disposal Units

Prepared for the U.S. Department of Energy, Richland Operations Office
Office of Environmental Restoration

Submitted by: Bechtel Hanford, Inc.

Available for a processing fee to U.S. Department of Energy and its contractors from:
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
(865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov
online ordering: http://www.doe.gov/bridge

Available for sale to the public, in paper, from:
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(800) 553-6847
fax: (703) 605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

Printed in the United States of America

DISCLM-5.CHP (11/99)

BHI-01293
Rev. 0
OU: 100-NR-1
TSD: 100-NR-1
ERA: N/A

APPROVAL PAGE

Title: Data Quality Objectives Summary Report for the 100-NR-1 Treatment, Storage, and Disposal Units

Approval: R. L. Donahoe, 100-N Task Lead

Donahoe
Signature

3/14/00
Date

The approval signature on this page indicates that this document has been authorized for information release to the public through appropriate channels. No other forms or signatures are required to document this information release.

BHI-01293
Rev. 0

Data Quality Objectives Summary Report for the 100-NR-1 Treatment, Storage, and Disposal Units

Author

J. D. Ludowise
CH2M Hill, Hanford, Inc.

Date Published

March 2000

EXECUTIVE SUMMARY

This data quality objective (DQO) summary report has been developed to support sampling and analysis of the 100-NR-1 Operable Unit treatment, storage, and disposal units during remediation and for closeout of the sites. The DQOs established by this document can be achieved by a judgmentally based sample design for the purpose of waste designation. Statistically based sampling will be used for the purpose of sampling the sites for closeout.

THIS PAGE INTENTIONALLY
LEFT BLANK

CONTENTS

APPENDIX

FIGURES

TABLES

TABLES (cont.)

THIS PAGE INTENTIONALLY
LEFT BLANK

ACRONYMS

AA	alternative action
AEA	alpha energy analysis
ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
BHI	Bechtel Hanford, Inc.
CHI	CH2M Hill Hanford, Inc.
CVAA	cold vapor atomic absorption
DR	decision rule
DS	decision statement
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
CMS	corrective measures study
COC	contaminant of concern
COPC	contaminant of potential concern
DQO	data quality objective
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
GeLi	germanium-lithium
HPGe	high-purity germanium
ICP	inductively coupled plasma
MCL	maximum contaminant level
MDL	minimum detection limit
MTCA	*Model Toxics Control Act*
NaI	sodium iodide
PQL	practical quantitation limit
PRG	preliminary remediation goal
PSQ	principal study question
RAG	remedial action goal
RAO	remedial action objective
RESRAD	RESidual RADioactivity dose model
RCRA	*Resource Conservation and Recovery Act of 1976*
RL	U.S. Department of Energy, Richland Operations Office
ROD	Record of Decision
RSD	relative standard deviation
TCLP	toxicity characteristic leachate procedure
TSD	treatment, storage, and disposal
OU	operable unit
UCL	upper confidence limit
WAC	*Washington Administrative Code*
WS	waste stream
XRF	x-ray fluorescence

THIS PAGE INTENTIONALLY
LEFT BLANK

METRIC CONVERSION CHART

The following conversion chart is provided to aid the reader in conversion.

Into Metric Units			Out of Metric Units		
If You Know	*Multiply By*	*To Get*	*If You Know*	*Multiply By*	*To Get*
Length			**Length**		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.0836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	hectares	2.47	acres
Mass (weight)			**Mass (weight)**		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			**Volume**		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			**Temperature**		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			**Radioactivity**		
picocuries	37	millibecquerel	millibecquerel	0.027	picocuries

1.0 STEP 1 – STATE THE PROBLEM

1.1 INTRODUCTION

Remedial actions will address contaminated soils, structures, and pipelines associated with four *Resource Conservation and Recovery Act of 1976* (RCRA) treatment, storage, and disposal (TSD) units and two associated sites. These TSD units and associated sites are located on the Hanford Site, near the Columbia River in the 100-NR-1 Operable Unit (OU).

The response actions are being taken under the authority of RCRA corrective action (Section 3004[u]); RCRA closure (Section 3005[e]); and the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remedial action (Section 121). By applying CERCLA authority jointly with that of RCRA, additional options for disposal of corrective action and remedial action wastes at the Environmental Restoration Disposal Facility (ERDF) are possible. The regulatory background has been detailed in a corrective measures study (CMS)/closure plan (DOE-RL 1998a).

1.2 FACILITY DESCRIPTIONS AND PROCESS HISTORY

Descriptions and process history information for each of the TSD units addressed by this data quality objective (DQO) summary report are provided in the following subsections. Figure 1-1 provides a map showing the locations of the TSD units.

Nine water-cooled, graphite-moderated, plutonium-production reactors were constructed along the Columbia River at the Hanford Site from 1943 to 1963. The 100-N Reactor, the last reactor to be built, is located in the 100 Areas in the northern part of the Hanford Site, on a broad strip of land along the Columbia River, about 48 km (30 mi) northwest of the city of Richland, Washington. The 100-N Reactor differs from the other reactors at the Hanford Site not only because of its closed-loop cooling system, but because it was designed as a dual-purpose reactor, capable of producing both special nuclear material and steam generation for electrical power. Although referred to as a "closed-loop cooling system," the system actually operated as a bleed-and-feed system where a portion of the cooling waters were constantly bled-off and replaced with fresh demineralized water. The cooling effluent removed from the loop eventually made its way to the 116-N-1 and 116-N-3 Liquid Waste Disposal Facilities. The 100-N Reactor began production in December 1963. The Hanford Generating Plant was completed and started producing electrical power in April 1966. Both the reactor and the generating plant operated continuously until January 7, 1987, except during periodic shutdowns for maintenance and repairs. The reactor was retired in October 1989 (WHC 1994), and orders were received to shut down the reactor in October 1991.

1.2.1 116-N-1 Crib and Trench and 116-N-3 Crib and Trench

The 116-N-1 Crib and Trench and the 116-N-3 Crib and Trench received radioactive liquid wastes containing activation and fission products, as well as small quantities of corrosive liquids and laboratory chemicals generated by various N Reactor operations. The units used the vadose zone to remove radioactive and hazardous materials from the effluent generated from reactor operations. As discharged effluent percolated through the soil column, most radioactive and chemical constituents were retained in the soil through filtration, absorption, adsorption, and ion exchange. However, some constituents (e.g., tritium) were not retained in the soil but instead traveled with the effluent. Eventually the soil's capacity to remove contaminants from the effluent was exceeded, allowing more contaminants to travel to the groundwater and on to the Columbia River.

The primary waste sources were the reactor cooling systems and the fuel storage basins. Essentially all of the strontium-90 and cesium-137 discharged to the 116-N-1 unit originated in the 100-N Reactor fuel storage basin. The water was discharged to the liquid waste disposal facilities at an average flow rate of 6,800 L/min (1,800 gal/min).

Various dangerous waste solutions were disposed in the units. These wastes resulted mainly from decontamination of the primary coolant system and from the possible disposal of chemicals to common floor drains that discharged to the units (WHC 1994). The chemicals that were introduced into the primary coolant system were ammonium hydroxide and hydrazine. Analysis of the primary coolant wastewater in 1985 indicated that the wastewater did not exhibit any of the characteristics of a regulated dangerous waste. Releases from the periphery cooling systems resulted in small continuous discharges of a variety of chemicals to the units, including ammonium hydroxide, morpholine, and hydrazine. Sodium dichromate was used as a corrosion inhibitor in the reactor cooling system and was discharged to the 116-N-1 unit until the early 1970s. Other discharges included drainage from reactor support facilities, five wet laboratories, and the auxiliary power battery lockers. Additional information on the N Reactor waste-generating processes is presented in the *100-N Area Technical Baseline Report* (WHC 1994).

1.2.1.1 116-N-1 Crib and Trench. The 116-N-1 unit is composed of two parts: a crib and a zig-zag-shaped trench. The crib area is approximately 88-m (289-ft) long by 38-m (125-ft) wide. The bottom of the crib is approximately 1.5 m (5 ft) below the level of the surrounding grade. A sloped soil and gravel embankment forms the walls of the crib. The crib was originally excavated to a depth of about 4.6 m (15 ft) below the level of the surrounding grade. The crib has been backfilled at various times with boulders and cobbles to control the spread of contamination. The three distinct layers of backfill are (1) the lowest layer, which is 0.9-m (3-ft) thick and consists of large boulders; (2) the middle layer, which is 0.6-m (2-ft) thick and is composed of smaller boulders; and (3) the upper layer, which is 1.2- to 1.5-m (4- to 5-ft) thick and consists of cobble-sized material.

The 116-N-1 Trench is 490-m (1,608-ft) long by 15-m (49-ft) wide at the top, with sloped side walls. Water spilled over a weir box in the dike (located on the north side of the crib) and into the trench. Wooden poles laid across the trench were used to support wire screening to keep birds out. This system of poles and netting was not completely effective in preventing wildlife intrusion, and airborne spread of contamination was also a problem. In early 1982, pre-cast concrete panels were installed to cover the entire trench as a further step to minimize wildlife intrusion and airborne contamination. These panels created a 15-m (50-ft)-wide cover over the top of the trench. The wooden poles and wildlife netting were not removed during installation of the cover panels.

1.2.1.2 116-N-3 Crib and Trench. The 116-N-3 unit is composed of two parts: a crib and a straight trench. The 116-N-3 Crib began operation in October 1983 as a replacement for 116-N-1, which had reached its disposal capacity. The 116-N-3 Crib is 76 m by 73 m (249 ft by 240 ft) and is covered by pre-cast concrete panels. The cover is about 1 m (3 ft) below the surrounding surface grade, and the bottom of the crib is 2 m (7 ft) below the cover. A water distribution system in the form of a network of concrete troughs rests on the bottom of the crib.

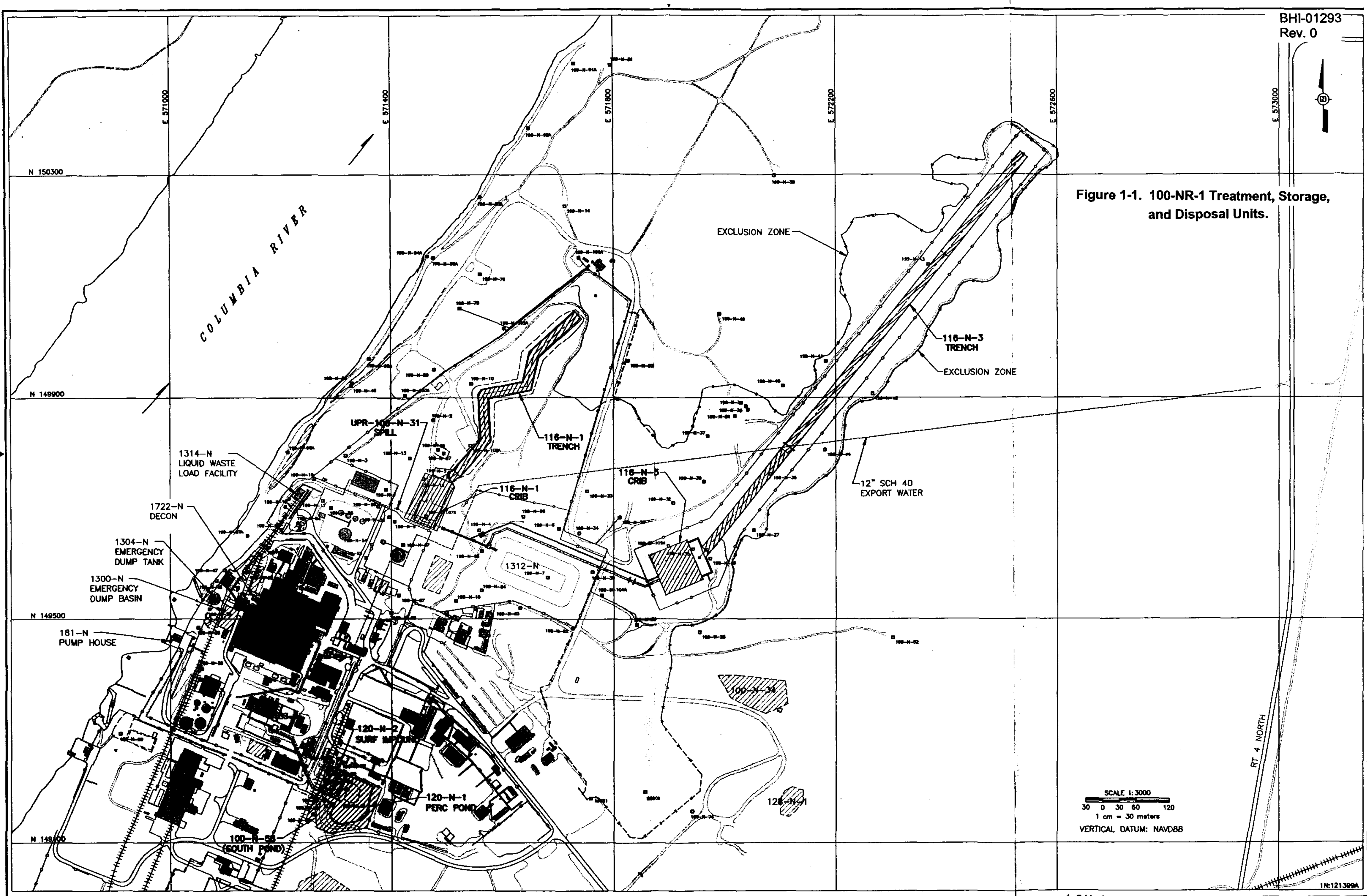


Figure 1-1. 100-NR-1 Treatment, Storage, and Disposal Units.

Water flowed from these troughs into the crib. Because of low percolation rates in the soil column, the 116-N-3 Crib was not able to achieve its designed flow capacity and the crib overflowed on two or three occasions. Each of the overflows traveled no more than 6 to 9 m (20 to 30 ft) from the concrete cover on the crib. All contamination remained within the fenced boundary, and each overflow was covered with a 15- to 20-cm (6- to 8-in.) layer of clean 2.5- to 5-cm (1- to 2-in.) river rock. After these initial incidents, the flow to 116-N-3 was controlled to prevent any further overflows.

Three months after the 116-N-3 Crib was placed into operation, the 116-N-3 straight extension trench was added. The trench ties into the crib at two points (from the crib's northern and eastern corners), with the effluent from these points combining in a common weir box. The tie-in is composed of rubber-gasket-joined, pre-cast, reinforced-concrete box sections. Effluent flowing through the weir box discharged into the trench through an overflow gate in the weir box. From the weir box, the trench extends about 914 m (3,000 ft) in a north-northeasterly direction.

The 116-N-3 Trench is 914-m (3,000-ft) long by 16.8-m (55-ft) wide and is covered with pre-cast concrete panels. Each panel is self-supporting and is approximately 17-m (55-ft) long and 3.1-m (10-ft) wide. The trench is divided into four equal-length sections by three dams. Only the first 226 m (740 ft) of the 116-N-3 Trench were used because effluent levels never rose high enough to cross the first dam. The dams are composed of structural fill and concrete. A layer of rip-rap was added on the downstream side of each dam to prevent scouring. The top 0.6 m (2 ft) of the trench bottom is a layer of 50- to 200-mm (2- to 8-in.) cobbles. The concrete panels are about 1 m (3 ft) below the surrounding grade, and the bottom of the trench is about 3 m (10 ft) below the concrete panels. The 116-N-3 straight extension trench was placed into full service in September 1985. In January 1987, N Reactor was placed on stand-down status for an extended maintenance and safety upgrade period, and the reactor was never restarted after that shutdown. Discharges to the 116-N-3 Trench decreased significantly at that time and ceased in April 1991.

1.2.2 Pipelines Associated with 116-N-1 and 116-N-3

Buried pipelines associated with the 116-N-1 and 116-N-3 sites consist of a total of 1,763 m (5,784 ft) of pipeline ranging in size from 8 to 91 cm (3.2 to 35.9 in.) in diameter, at an average depth of 3.7 m (12 ft). Because there is no process history indicating that the pipelines leaked, there is no known soil contamination associated with the pipelines. Nevertheless, it is possible that leaks have occurred but went undetected. The condition of the pipelines, internal contamination, and the extent and nature of any soil contamination that may be present will be assessed during the remedial design/remedial action phase of the project.

1.2.3 UPR-100-N-31

The UPR-100-N-31 spill occurred on July 22, 1974, while sample lines were being installed in a 15-cm (6-in.) steel casing through the berm on the west side of the 116-N-1 Crib. During the sample line installation, the water level in the crib was raised from 38 to 46 cm (15 to 18 in.) as a result of an emergency dump tank drawdown test. Due to the increased water level, approximately 4,000 L (1,056 gal) of effluent water containing fission and activation products flowed through the casing and were discharged to the soil. An area of approximately 188 m^2 (2,023 ft^2) was contaminated. Sand and fines were used to stabilize the soil contamination before its removal and disposal at the 200 Areas. After the contaminated soil was removed, clean fill material was used to restore the site. Some residual contamination may remain at this site because the cleanup that was performed in 1974 was not performed to today's cleanup standards.

1.2.4 120-N-1, 120-N-2, and 100-N-58 Percolation Pond System

The percolation pond system received nonradioactive liquid corrosive wastes from the 163-N Demineralization Plant and the 183-N Water Filter Plant. Before 1977, the effluent from 163-N Demineralization Plant was discharged to the Columbia River, which was the common practice of industry at that time. Beginning in 1977, the effluent was discharged to the 120-N-1 Percolation Pond. The *100-N Area Technical Baseline Report* (WHC 1994) summarizes the waste treatment practice as the alternate addition of acidic cation regenerate and alkaline anion regenerate to neutralize the pH of 163-N Demineralization Plant's effluent over time.

1.2.4.1 120-N-1 Percolation Pond. The 120-N-1 Percolation Pond has a capacity of 11.4 million L (3 million gal), and the bottom area is approximately 2,700 m^2 (29,052 ft^2). After treatment in the 120-N-2 Surface Impoundment (see Section 1.2.4.2), neutralized wastewater was transferred to the 120-N-1 Percolation Pond by a system of overflow and drain lines, where the effluent discharged to the soil column.

1.2.4.2 120-N-2 Surface Impoundment. The 120-N-2 Surface Impoundment is a double-lined pond (with two 1.1-mm [0.04-in.] liners) with a leachate collection system. The impoundment was built in the location of the old North Settling Pond, which had previously received corrosive waste and filter backwash water from the 163-N Demineralization Plant and the 183-N Water Filter Plant. The impoundment measures approximately 43 m by 23 m (141 ft by 75 ft) at the surface. The sides of the pond slope to the bottom, which measures approximately 24 m by 4.6 m (79 ft by 15 ft), and the pond has a design capacity of 1.6 million L (0.4 million gal).

1.2.4.3 100-N-58 Settling Pond. The 100-N-58 Settling Pond measured approximately 34 m by 15 m (112 ft by 49 ft) at the surface, with the sides sloping to the bottom and measuring approximately 24 m by 3 m (79 ft by 10 ft), and an estimated depth of 4.5 m (14.8 ft). The 100-N-58 Settling Pond originally received corrosive waste and filter backwash water from the 163-N Demineralization Plant and the 183-N Water Filter Plant in parallel with the 120-N-2 Pond. In 1983, when the liner was installed in the 120-N-2 Surface Impoundment, the 100-N-58 Settling Pond was backfilled to grade.

1.2.5 Pipelines Associated with the 120-N-1, 120-N-2, and 100-N-58 Percolation Pond System

Buried pipelines associated with the 120-N-1, 120-N-2, and 100-N-58 percolation pond system consist of approximately 296 m (971 ft) of pipeline ranging in size from 20 to 30 cm (8 to 12 in.) in diameter, at an average depth of 3.7 m (12 ft). Several pipelines that were removed from service were likely abandoned in place.

1.3 PROJECT GOALS

The purpose of the project is to remediate the 100-NR-1 TSD sites identified in the 100-NR-1 interim remedial action Record of Decision (ROD) (Ecology et al. 2000) that have received radioactive waste (i.e., the 116-N-1, 116-N-3, associated pipelines, and UPR-100-N-31). The selected remedy includes excavation, waste disposal, and backfill of the waste sites. This project will not implement work that is outside of the scope of the interim remedial action ROD or the CMS/closure plan (DOE-RL 1998a) for the nonradioactive sites.

The project goals are as follows:

- Remove soils that exceed direct exposure remedial action objectives (RAOs) for rural-residential exposure up to a depth of 4.6 m (15 ft) below surrounding grade or to the bottom of the engineered structure, whichever is deeper. The RAOs for rural-residential exposure are 15 mrem/yr above natural background for radionuclides and the State of Washington's *Model Toxics Control Act* [MTCA] Method B values for nonradioactive contaminants (*Washington Administrative Code* [WAC] 173-340).

- Remove soils to a depth of 1.5 m (5 ft) below the engineered structures of the 116-N-1 and 116-N-3 units that contain plutonium-239/240 contaminants greater than 15 mrem/yr above natural background.

- Remove soils that exceed standards for the protection of groundwater and the Columbia River. For sites where soil contamination in excess of the groundwater or river cleanup standards is present more than 4.6 m (15 ft) below surrounding grade, several balancing factors will be considered to determine the extent of additional remediation. These factors include reduction of risk by decay of short-lived radionuclides, protection of human health and the environment, remediation costs, size of the ERDF, worker safety, presence of ecological and cultural resources, the use of institutional controls, and long-term monitoring costs.

- Remove pipelines associated with the TSD units where contamination levels associated with the pipelines exceed remedial action goals (RAGs). Treat as necessary and dispose of waste in the ERDF or as appropriate.

Because approximately three-quarters of the 116-N-3 Trench did not receive radioactive effluent, an underlying assumption is that that part of the trench is clean. Therefore, an implicit goal of this project is to identify the location (near the first dam) beyond which the 116-N-3 Trench soils no longer exceed direct exposure and groundwater/river protection cleanup standards.

The project will also implement the closure of the 120-N-1, 120-N-2, and 100-N-58 sites as specified in the closure plan (Appendix B of DOE-RL [1998a]). Closure involves removing the liner in the 120-N-2 Surface Impoundment, removing the sampling shed and fencing that surround the sites, and removing the feed pipeline if it is found to be contaminated.

There will be no remediation excavation in the 120-N-1, 120-N-2, and 100-N-58 earthen basins for closure. However, the Hypalon liner, sampling shed, and perimeter fence will be demolished and removed. The demolished components will be disposed in an appropriate nonhazardous disposal facility or recycled as scrap, as appropriate, and will be characterized appropriately to this end.

The data presented in the closure plan (Appendix B of DOE-RL [1998a]) indicate that the vadose zone under the 120-N-1, 120-N-2, and 100-N-58 sites did not contain concentrations of metals that are distinguishable from background. The data used to lead to this conclusion were obtained from samples located in areas expected to record adverse impacts from the units. An exception is the lack of data from samples that may have been influenced by an overflow of the North Settling Pond. There are some indications that this event may have occurred and that standing water was present in the northern portion of the units. To evaluate any impacts from an event of this kind, two samples will be collected from the northern part of the units.

Tables 1-1, 1-2, and 1-3 identify the DQO scoping team members, the DQO workshop team members, and the key decision makers, respectively. The DQO scoping team developed the checklist and binder prior to beginning the seven-step DQO process. The DQO workshop team members participated in the seven-step process, and the key decision makers provided the external review of the results of the seven-step DQO process.

Table 1-1. DQO Scoping Team Members.

Name	Organization	Area of Expertise (Role)	Phone Number
B. Mukherjee	BHI Project Engineer	BHI Project Engineer	372-9218
C. W. Hedel	CHI Environmental Engineering	CHI Project Lead	372-9602
R. W. Ovink	CHI Regulatory Support and Environmental Sciences	DQO Facilitator	372-9631
J. D. Ludowise	CHI Environmental Engineering	Design Engineer	372-9324
J. W. Badden	CHI Regulatory Support and Environmental Sciences	Regulatory Analysis	372-9698
R. W. Jackson	BHI Field Services Waste Management	Waste Management	373-5473
S. K. DeMers	BHI RadCon Engineering	Radiation Control and Protection	531-0729
S. G. Weiss	CHI Regulatory Support and Environmental Sciences	Ecological Resources Protection	372-9531
W. J. Adam	CHI Safety and Health	Safety Analysis	372-9311
S. W. Clark	CHI Regulatory Support and Environmental Sciences	Risk Scenarios/Pathways	372-9613
J. J. Sharpe	CHI Regulatory Support and Environmental Sciences	Cultural Resource Protection	372-9369

BHI = Bechtel Hanford, Inc.
CHI = CH2M Hill Hanford, Inc.
RadCon = Radiological Control

Table 1-2. DQO Workshop Team Members. (2 pages)

Name	Organization	Area of Expertise (Role)	Phone Number
B. Mukherjee	BHI Project Engineer	BHI Project Engineer	372-9218
C. W. Hedel	CHI Environmental Engineering	CHI Project Lead	372-9602
R. W. Ovink	CHI Regulatory Support and Environmental Sciences	DQO Facilitator	372-9631
J. D. Ludowise	CHI Environmental Engineering	Design Engineer	372-9324
J. W. Badden	CHI Regulatory Support and Environmental Sciences	Regulatory Analysis	372-9698

Table 1-2. DQO Workshop Team Members. (2 pages)

Name	Organization	Area of Expertise (Role)	Phone Number
G. J. Borden	BHI Field Services Waste Management	Waste Management	373-1915
S. K. DeMers	BHI RadCon Engineering	Radiation Control and Protection	531-0729
S. G. Weiss	CHI Regulatory Support and Environmental Sciences	Ecological Resources Protection	372-9531
W. J. Adam	CHI Safety and Health	Safety Analysis	372-9311
S. W. Clark	CHI Regulatory Support and Environmental Sciences	Risk Scenarios/Pathways	372-9613
J. J. Sharpe	CHI Regulatory Support and Environmental Sciences	Cultural Resource Protection	372-9369
A. Antipas	CH2M Hill	Chemist	(425) 453-5005, ext. 5051
A. Turner	CH2M Hill	Statistician	(518) 756-1657
W. S. Thompson	BHI Site Assessments and Closeout	Sampling and Onsite Measurements Scientist	372-9597
S. Blackburn	SAIC	Statistician	372-7754

Table 1-3. DQO Key Decision Makers.

Name	Organization	Area of Expertise (Role)	Phone Number
G. I. Goldberg	RL Restoration Projects Division	Decision maker	376-9552
F. W. Bond	Washington State Department of Ecology	Decision maker	736-3037
D. A. Faulk	U. S. Environmental Protection Agency	Decision maker	376-8631

RL = U.S. Department of Energy, Richland Operations Office

Figure 1-2 contains a process diagram for the DQO scoping/workbook/conceptual site model development process. The DQO scoping/conceptual site model/DQO/sampling and analysis plan development process is depicted in the process diagram shown in Figure 1-3.

Figure 1-2. DQO Scoping/Workbook/Conceptual Site Model Development Process.

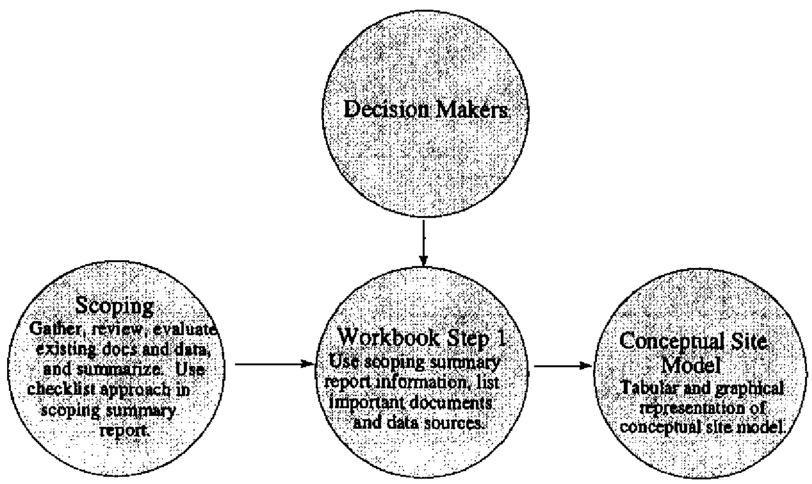
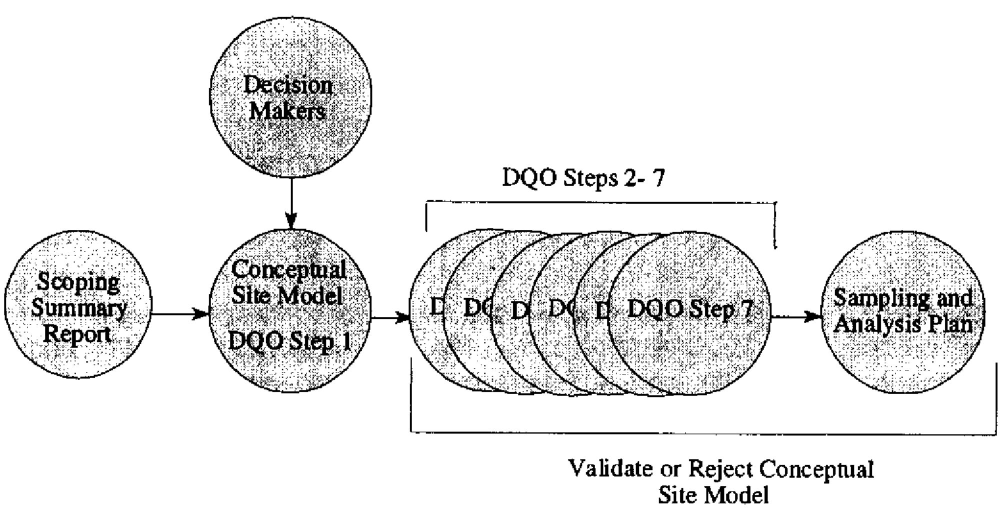


Figure 1-3. DQO Scoping/Conceptual Site Model/ DQO/SAP Development Process.



The documents listed in Table 1-4 were used to support the descriptions for the each of the TSD units for this project.

Table 1-4. Existing Documents and Data Sources.

Reference	Summary
Qualitative Risk Assessment for the 100-NR-1 Source Operable Unit, BHI-00054, Rev. 1 (BHI 1995a)	Identifies risks at some of the source waste sites in the 100-N Area that may warrant remedial action.
Qualitative Risk Assessment for the 100-NR-2 Operable Unit, BHI-00055, Rev. 1 (BHI 1995b)	Determined that some contaminant concentrations in groundwater exceed health-based risk levels.
Data Quality Objectives Workshop Results for 1301-N and 1325-N Characterization, BHI-00368, Rev. 0 (BHI 1996)	Presents DQOs for the limited field investigation characterization.
1301-N and 1325-N Liquid Waste Disposal Facilities Limited Field Investigation Report, DOE/RL-96-11, Rev. 0 (DOE-RL 1996)	The results of a study were used to determine if soil remediation was required to protect groundwater from a future potential impact and, if so, when remediation should be performed.
100-NR-1 Treatment, Storage, and Disposal Units Corrective Measures Study/Closure Plan, DOE/RL-96-39, Rev. 0 (DOE-RL 1998a)	Conducted to gather information to support selection of a remedial alternative to address contamination at the four 100-NR-1 TSD units and the two associated sites
Proposed Plan for Interim Remedial Action and Dangerous Waste Modified Closure of the Treatment, Storage, and Disposal Units and Associated Sites in the 100-NR-1 Operable Unit, DOE/RL-97-30, Rev. 0 (DOE-RL 1998b)	Presents the proposed plan for interim remedial action and dangerous waste modified closure of the sites.
100-NR-1 Treatment, Storage, and Disposal Units Engineering Study, BHI-01092, Rev. 1 (BHI 1999b)	Evaluated options for remediation of the 116-N-1 and 116-N-3 sites. Recommended alternative of boxing highly contaminated soil for disposal in the ERDF. Also recommended additional characterization to better define the nature and extent of contamination.
Environmental Restoration Disposal Facility Waste Acceptance Criteria, BHI-00139, Rev. 3 (BHI 1998a)	Identifies the criteria for accepting mixed waste at the ERDF.
Field Investigation Plan for 1301-N and 1325-N Facilities Sampling to Support Remedial Design, BHI-01236, Rev. 1 (BHI 1998b)	Sampling plan for characterization work identified in the engineering study (BHI 1999b).
Data Summary Report for 116-N-1 and 116-N-3 Facility Soil Sampling to Support Remedial Design, BHI-01271, Rev. 0 (BHI 1999c)	Presents the results of the characterization work performed under the field investigation plan (BHI 1998b). Concluded that extent of contamination is significantly less than was assumed in the engineering study (BHI 1999b).

Table 1-5 identifies the contaminants of potential concern (COPCs) that were identified in the CMS/closure plan (DOE-RL 1998a). The table lists the known or suspected sources of contamination, the type of contamination, a list of the COPCs, and the affected environmental media.

Ammonium hydroxide was added to the water used for reactor graphite and shield cooling to maintain a pH of approximately 10 and reactor control rod cooling to maintain a pH of approximately 7. The concentration of ammonium hydroxide was about 40 ppm in both cooling systems. Ammonium hydroxide is not listed in WAC 73-303-9903. The MTCA Method B formula value for ammonia (i.e., the same as ammonium hydroxide) is 2.72 X 10^6 ppm. No human health or environmental threats are posed by ammonium hydroxide at low concentrations (40 ppm), so it is not considered a COPC.

Morpholine was added to the water in the reactor secondary coolant loop to control pH between 8.6 and 9.2. The concentration of morpholine in the cooling water was about 4 ppm. Morpholine is not listed in WAC 173-303-9903 and it was not present in the cooling water in high enough concentration to be considered ignitable. There is no MTCA Method B formula value for morpholine. No human health or environmental threats are posed by morpholine at low concentrations (4 ppm), so it is not considered a COPC.

Hydrazine was added to the graphite and shield cooling water, reactor control rod cooling water, and the reactor secondary cooling water to scavenge oxygen and thereby reduce corrosion. The concentration of hydrazine in the cooling water was 0.04, 0.15 and 1 ppm in the graphite and shield cooling water, reactor control rod cooling water, and the reactor secondary cooling water, respectively. Hydrazine is listed in WAC 173-303-9903 (code U133). However, the discharge of hydrazine involved a release of material that was in use within the process and is not designated as a discarded commercial product; therefore, hydrazine is not designated as a dangerous waste. The MTCA Method B formula value for hydrazine in soils is 0.33 ppm. Hydrazine was used in very low concentrations and is a powerful reducing agent so it would decompose upon contact with naturally occurring organic materials and metallic oxides that are present in the soils. No human health or environmental threats are posed by hydrazine, so it is not considered a COPC.

Methanol is a dangerous waste reported in the RCRA dangerous waste permit application for the 116-N-1 and 116-N-3 sites. Methanol was used at the 100-N laboratories and may have been disposed in the laboratory floor drains that emptied into the 116-N-1 and 116-N-3 sites. Methanol is regulated as a "F003" waste because of its characteristic of ignitability. Under 40 CFR 261.3(a)(2)(iii), wastes listed solely due to a characteristic are no longer listed when a waste mixture no longer exhibits the characteristic. Methanol would have been diluted with large amounts of water, so the concentration of methanol in water disposed to the 116-N-1 and 116-N-3 sites would have been very low (less than 30 ppm). At this concentration, methanol would not be ignitable.

Unlike the Federal regulations, the Washington State dangerous regulations do not allow for removal of listed waste codes in situations where the listing is based solely on characteristics and a waste mixture does not exhibit the characteristic. As a consequence, the "state-only" listed waste code can be assigned. However, Ecology has acknowledged that Federal land disposal restrictions do not apply to state-only listed waste. The 100-NR-1 CERCLA ROD acknowledges the state-only listed "F003" waste code associated with wastes arising from remedial actions at the cribs/trenches, and states that "...it is anticipated that these F003 wastes will meet ERDF waste acceptance criteria without the need for treatment due to very low concentrations of methanol." Therefore, methanol is not a COPC for purposes of waste disposal.

Methanol readily biodegrades and is not expected to be present in measurable concentrations. The MTCA Method B formula value for methanol in soil is 4,000 ppm. No human health or environmental threats are posed by methanol, so it is not considered a COPC for the purposes of site cleanup.

An underlying assumption of this DQO process is that any contamination from past releases at any sites that are not identified in the CMS (DOE-RL 1998a) is not within the scope of the remedial action and is, therefore, not within the scope of this DQO process.

Table 1-5. Sources of Contamination, COPCs, and Affected Media (from DOE-RL 1998a). (3 pages)

[illegible]	[illegible]	[illegible]	COPC (Specific Contamination)	Affected Media
1	116-N-1 Crib, UPR-100-N-31, and associated pipelines	Radionuclides	Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Thorium-232 Tritium Uranium-233/234 Uranium-238	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines
			Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Thorium-232 Tritium Uranium-233/234 Uranium-238	Subsurface (>4.6 m [>15 ft] bgs) soil
		Inorganics	Cadmium Chromium (total) Chromium (VI) Lead Mercury Nitrate	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines
			Cadmium Chromium (total) Chromium (VI) Lead Mercury Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil

Table 1-5. Sources of Contamination, COPCs, and Affected Media (from DOE-RL 1998a). (3 pages)

WS #	Known or Suspected Source of Contamination (Process/Waste Stream)	Type of Contamination from Each Source (General Contamination)	COPCs (Specific Contamination)	Affected Media
2	116-N-1 Trench and cover panels	Radionuclides	Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Thorium-232 Tritium Uranium-233/234 Uranium-238	Subsurface (>4.6 m [>15 ft] bgs) soil and concrete structures
		Inorganics	Cadmium Chromium (total) Chromium (VI) Lead Mercury Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil and concrete structures
3	116-N-3 Crib, Trench, cover panels, and associated pipelines	Radionuclides	Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Thorium-228 Thorium-232 Tritium Uranium-233/234 Uranium-238	Subsurface (>4.6 m [>15 ft] bgs) soil, concrete structures, and pipelines
		Inorganics	Cadmium Lead Mercury Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil, concrete structures, and pipelines

Table 1-5. Sources of Contamination, COPCs, and Affected Media (from DOE-RL 1998a). (3 pages)

WS[a]	Known or Suspected Source of Contamination (Process/Waste Stream)	Type of Contamination from Each Source (Category of Contamination)	COPCs (Specific Contaminants)[b]	Affected Media
4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	Radionuclides	None (see Table 2-15 of the CMS [DOE-RL 1998a])	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines
		Inorganics	Antimony Arsenic Barium Beryllium Cadmium Chromium (total) Chromium (VI) Copper Lead Manganese Mercury Nickel Selenium Silver Sulfate Thallium Vanadium Zinc pH	Northern part of the units, surface (0 to 4.6 m [0 to 15 ft] bgs) soil (see page B-26 of the CMS [DOE-RL 1998a])

[a] Remediation projects refer to the "process (P)"; decontamination and decommissioning projects or projects with multiple sources of contamination refer to the "waste stream (WS)."
[b] Except for americium-241 and nickel-63, COPCs are taken from the CMS/closure plan (DOE-RL 1998a). Americium-241 was added to the list because it is an alpha particle emitter and is generally present whenever plutonium from weapons production is present. Nickel-63 was added because it is an activation product that has been frequently observed in other 100 Area remediation projects.
bgs = below ground surface

Table 1-6 identifies the list of COPCs that were excluded from the investigation and the rationale for their exclusion.

Table 1-6. COPC Exclusions and Justifications. (2 pages)

WS	COPCs Excluded	Media	Rationale for Exclusion
1 – 116-N-1 Crib, UPR-100-N-31, and associated pipelines	Thorium-232 Uranium-233/234 Uranium-238 Cadmium Chromium (total) Chromium (VI) Lead	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Contaminant concentrations are less than PRGs. See Chapter 4.0 of the CMS (DOE-RL 1998a).

Table 1-6. COPC Exclusions and Justifications. (2 pages)

WS #	COPCs Excluded	Media	Rationale for Exclusion
	Cesium-137 Cobalt-60 Europium-154 Europium-155 Thorium-232 Uranium-233/234 Uranium-238 Cadmium Lead Mercury	Subsurface (>4.6 m [>15 ft] bgs) soil	Contaminant concentrations are less than PRGs. See Chapter 4.0 of the CMS (DOE-RL 1998a). However, cesium-137 is not excluded from the deep zone because it is found in the groundwater underlying the sites.
2 – 116-N-1 Trench and cover panels	Cesium-137 Cobalt-60 Europium-154 Europium-155 Thorium-232 Uranium-233/234 Uranium-238 Cadmium Lead Mercury	Subsurface (>4.6 m [>15 ft] bgs) soil and concrete structures	Contaminant concentrations are less than PRGs. See Chapter 4.0 of the CMS (DOE-RL 1998a). However, cesium-137 is not excluded from the deep zone because it is found in the groundwater underlying the sites.
3 – 116-N-3 Crib and Trench, cover panels, and associated pipelines	Cesium-137 Cobalt-60 Europium-154 Europium-155 Thorium-228 Thorium-232 Uranium-233/234 Uranium-238 Cadmium Lead Mercury	Subsurface (>4.6 m [>15 ft] bgs) soil, concrete structures, and pipelines	Contaminant concentrations are less than PRGs. See Chapter 4.0 of the CMS (DOE-RL 1998a). However, cesium-137 is not excluded from the deep zone because it is found in the groundwater underlying the sites.
4 – 120-N-1, 120-N-2, 100-N-58, and associated pipelines	None	0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	No radiochemical COPCs identified at these sites; all nonradiochemical COPCs are retained. See page B-26 of the CMS (DOE-RL 1998a).

PRG = preliminary remediation goal

A final list of contaminants of concern (COCs) and the rationale for their inclusion are provided in Table 1-7.

Table 1-7. Final COC List. (2 pages)

WSC	COC	Media	Rationale for Inclusion
Radioactive Constituents			
1 – 116-N-1 Crib, UPR-100-N-31, and associated pipelines 2 – 116-N-1 Trench and cover panels 3 – 116-N-3 Crib and Trench, cover panels, and associated pipelines	Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Tritium	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Contaminant concentrations exceed PRGs. See interim remedial action ROD (Ecology et al. 2000). Americium-241 is retained because it is an alpha particle emitter associated with plutonium from weapons production. Nickel-63 is added because it is a common activation product and has been found in other 100 Area sites. Strontium-90 is added in the deep zone because it is found in the groundwater underlying the sites.
	Americium-241 Nickel-63 Plutonium-239/240 Strontium-90 Tritium	Subsurface (>4.6 m [>15 ft] bgs) soil	
4 – 120-N-1, 120-N-2, 100-N-58, and associated pipelines	None	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	No radioactive contaminants of concern identified in the CMS (DOE-RL 1998a).
For purposes of waste characterization, all radioactive sites	Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Tritium	Soil, concrete structures, and pipelines	Necessary for waste characterization.
Chemical Constituents			
1 – 116-N-1 Crib, UPR-100-N-31, and associated pipelines 2 – 116-N-1 Trench and cover panels	Nitrate Mercury	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Contaminant concentrations exceed PRGs. See interim remedial action ROD (Ecology et al. 2000).
	Chromium (total) Chromium (VI) Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil and concrete structures	
3 – 116-N-3 Crib and Trench, cover panels, and associated pipelines	Nitrate Mercury	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	
	Nitrate	Subsurface (>4,6 m [>15 ft bgs]) soil, concrete structures, and pipelines	

Table 1-7. Final COC List. (2 pages)

WS #	COCs	Media	Rationale for Inclusion
4 – 120-N-1, 120-N-2, 100-N-58, and associated pipelines	Antimony Arsenic Barium Beryllium Cadmium Chromium (total) Chromium (VI) Copper Lead Manganese Mercury Nickel Selenium Silver Sulfate Thallium pH Vanadium Zinc	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil	See page B-26 of the CMS (DOE-RL 1998a).

Table 1-8 identifies all COC migration pathways. These migration pathways are taken from the CMS (DOE-RL 1998a).

Table 1-8. COC Exposure and Migration Pathways (from DOE-RL 1998a). (2 pages)

WS #	COCs	Media	Exposure/Migration Pathways
1 – 116-N-1 Crib, UPR-100-N-3, and associated pipelines	Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Tritium	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Ingestion, inhalation, and external exposure; migration to groundwater and the Columbia River.
	Nitrate Mercury	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Ingestion; migration to groundwater and the Columbia River.
	Americium-241 Tritium Nickel-63 Plutonium-239/240 Strontium-90	Subsurface (>4,6 m [>15 ft] bgs) soil	Migration to groundwater and the Columbia River.
	Chromium Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil	Migration to groundwater and the Columbia River.

Table 1-8. COC Exposure and Migration Pathways (from DOE-RL 1998a). (2 pages)

WS	COCs	Media	Exposure/Migration Pathways
2 – 116-N-1 Trench and cover panels	Americium-241 Tritium Nickel-63 Plutonium-239/240 Strontium-90	Subsurface (>4.6 m [>15 ft] bgs) soil and concrete structures	Migration to groundwater and the Columbia River.
	Chromium Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil and concrete structures	Migration to groundwater and the Columbia River.
3 – 116-N-3 Crib, Trench, cover panels, and associated pipelines	Americium-241 Tritium Nickel-63 Plutonium-239/240 Strontium-90	Subsurface (>4.6 m [>15 ft] bgs) soil, concrete structures, and pipelines	Migration to groundwater and the Columbia River.
	Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil, concrete structures, and pipelines	Migration to groundwater and the Columbia River.
4 – 120-N-1, 120-N-2, 100-N-58, and associated pipelines	Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Lead Manganese Mercury Nickel Selenium Silver Thallium Sulfate pH Vanadium Zinc	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Migration to groundwater and the Columbia River.

The potential human and environmental receptors are identified in Table 1-9. The potential human and environmental receptors are taken from the CMS (DOE-RL 1998a).

Table 1-9. Human and Environmental Receptors (from DOE-RL 1998a).

WS #	COCs	Media	Human Receptors (from Section 3.3.1 in the CMS [DOE-RL 1998a])	Ecological Receptors (from Section 3.3.1 in the CMS [DOE-RL 1998a])
1 – 116-N-1 Crib, UPR-100-N-3, and associated pipelines	Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Tritium Nitrate Mercury	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Current worker, future worker, occasional user, and future resident	Terrestrial
	Americium-241 Tritium Nickel-63 Plutonium-239/240 Strontium-90 Chromium Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil	None	Aquatic, riparian
2 – 116-N-1 Trench and cover panels	Americium-241 Tritium Nickel-63 Plutonium-239/240 Strontium-90 Chromium Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil and concrete structures	None	Aquatic, riparian
3 – 116-N-3 Crib, Trench, cover panels, and associated pipelines	Americium-241 Tritium Nickel-63 Plutonium-239/240 Strontium-90 Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil, concrete structures, and pipelines	None	Aquatic, riparian
4 – 120-N-1, 120-N-2, 100-N-58, and associated pipelines	Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Lead Manganese Mercury Nickel Nitrate Selenium Silver Thallium Sulfate pH Vanadium Zinc	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Current worker, future worker, occasional user, and future resident	Aquatic, riparian

The current and potential future land uses of the site are identified in Table 1-10.

Table 1-10. Current and Potential Future Site Land Use.

Current Land Use	Potential Future Land Use
Industrial	Preservation, conservation, and recreation[a]

[a] Future land uses are identified in the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE 1999). While none of the proposed future land uses include residences, a rural-residential exposure scenario is being assumed to calculate cleanup levels as specified in the interim remedial action ROD (Ecology et al. 2000).

Table 1-11 lists the preliminary applicable or relevant and appropriate requirements (ARARs) and preliminary remediation goals (PRGs) for the TSD units.

Table 1-11. List of Preliminary ARARs and PRGs. (2 pages)

COPC	Preliminary ARARs	PRG	
		Soil 0 to 4.6 m (0 to 15 ft) bgs for Surface Exposure	Subsurface Soil >4.6 m (>15 ft) bgs to Groundwater/River Protection
Radionuclides (pCi/g)			
Americium-241	Draft EPA standard of 15 mrem/yr above background for protection of human health (40 CFR 196). Concentrations represent the 15 mrem/yr limit for each radionuclide alone. MCLs promulgated under the Federal *Safe Drinking Water Act* (40 CFR 141) that correspond to 4 mrem/yr. Concentrations represent the 4 mrem/yr limit for each radionuclide alone.	41.6[b]	[c]
Cesium-137		6.1	[c]
Cobalt-60		1.4	[c]
Europium-154		3.1	[c]
Europium-155		127	[c]
Nickel-63		4,031[b]	[c]
Plutonium-239/240		23.5	[c]
Strontium-90		3.7	[c]
Tritium		241	2,000
Inorganics (mg/kg)			
Antimony	MTCA Non-zero MCL goals and MCL promulgated under the Federal *Safe Drinking Water Act* (40 CFR 141) and/or the State of Washington (WAC 246-290). Ambient water quality criteria developed under the Federal *Clean Water Act* (Section 304) or standards promulgated by the State of Washington (WAC 173-201).	32	---
Arsenic		20[d]	20[d]
Barium		5,600	[c]
Beryllium		400	---
Cadmium		80	[c]
Chromium (III)		80,000	[c]
Chromium (VI)		400	2
Copper		2,960	---
Lead		353[e]	[c]
Manganese		11,200	---
Mercury		24	[c]
Nickel		1,600	---
Nitrate		113,000	4,400
Selenium		400	[c]

Table 1-11. List of Preliminary ARARs and PRGs. (2 pages)

COC	Preliminary ARAR	PRG	
		Soil: 0 to 4.6 m (0 to 15 ft) bgs for Surface Exposure	Subsurface Soil: >4.6 m (>15 ft) bgs for Groundwater/River Protection
Silver		400	[c]
Sulfate		N/A	25,000
Thallium		6	---
pH (pH units)		<2 or >12.5	<2 or >12.5
Vanadium		560	---
Zinc		24,000	---
Organics (mg/kg)			
None	---	---	---

[a] Where regulations (ARARs) differ, the value listed is from the more restrictive regulation.
[b] Except for americium-241 and nickel-63, radionuclide values are from Table 2 of the interim remedial action ROD (EPA et al. 2000) and represent the single radionuclide soil concentration corresponding to a 15 mrem/yr dose. Values for americium-241 and nickel-63 were calculated using the RESidual RADioactivity dose model (RESRAD), Version 5.91 (ANL 1993).
[c] The RESRAD unit gradient model predicts that the contaminant will not reach groundwater within 1,000-year time frame.
[d] Arsenic limits are from MTCA Method A due to high background values per discussions with regulators.
[e] A MTCA Method B value for lead is not available. This value is based on EPA's *Integrated Exposure Uptake Biokinetic Model for Lead in Children* (EPA 1994a).
CFR = *Code of Federal Regulations*
EPA = U.S. Environmental Protection Agency
MCL = maximum contaminant level
N/A = not applicable

The potential exposure scenarios for the TSD units are identified in Table 1-12.

Table 1-12. Exposure Scenarios.

Scenario	Exposure Scenario Description (from Section 3.3.1 of CMS [DOE-RL 1998a])
Rural-residential	Human receptor -- Ingestion of contaminated soils, external dose from soils, inhalation of contaminated dust, and ingestion of contaminated plants and animals. Ecological receptor -- Ingestion of contaminated soils, water, and food; external dose from soils; inhalation of contaminated dust; and uptake of contaminants through gill structure or other permeable organs.

Table 1-13 provides information on the tabular site conceptual model.

Table 1-13. Tabular Site Conceptual Model. (2 pages)

Toxics	Primary Source	Primary Release Mechanism	Secondary Source	Secondary Release Mechanism	Exposure Pathways	Receptors
Am-241	Fuel element	Rupture	116-N-1/ 116-N-3 Crib/Trench sediments	Resuspension, deposition, biotic uptake, infiltration/ percolation, leaching, radiation, excavation/ direct contact	Ingestion, dermal contact, inhalation, external radiation	Current worker, future worker, occasional user, future resident, terrestrial species, aquatic species, riparian species
Cs-137	Fuel element	Rupture				
Co-60	Activation product	Activation of materials surrounding reactor fuel				
Eu-154	Fuel element	Rupture				
Eu-155	Fuel element	Rupture				
Ni-63	Activation product	Activation of nickel in steel and stainless steel				
Pu-239/240	Fuel element	Rupture				
Sr-90	Fuel element	Rupture				
Tritium	Activation product	Activation of cooling water				
Nitrate	Reactor decontam-ination	Flushing of decontam-ination solution		Resuspension, deposition, biotic uptake, infiltration/ percolation, leaching, excavation/ direct contact	Ingestion, dermal contact, inhalation	Current worker, future worker, occasional user, future resident, terrestrial species, aquatic species, riparian species
Mercury	Instruments	Breakage				
Chromium	Reactor decontam-ination/anti-corrosion	Flushing of decontam-ination solution				

Table 1-13. Tabular Site Conceptual Model. (2 pages)

COCs	Primary Source	Primary Release Mechanism	Secondary Source	Secondary Release Mechanism	Migration Pathways	Receptor
Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Lead Manganese Mercury Nickel Nitrate Selenium Silver Thallium Sulfate Vanadium Zinc pH	Water treatment	Process backflushes, ion exchange, regeneration waste, etc.	120-N-1, 120-N-2, and 100-N-58 sediments	Resuspension, deposition, biotic uptake, infiltration/ percolation, leaching, excavation/ direct contact	Ingestion, dermal contact, inhalation	Current worker, future worker, occasional user, future resident, terrestrial species, aquatic species, riparian species

Figure 1-4 provides a graphic of the conceptual site model.

Figure 1-4. Graphical Description of the Conceptual Site Model (from DOE-RL 1998a).

Exposure		*Human Receptors*			
		Radionuclides		*Nonradionuclides*	
Media	**Route**	*Rural Residential*	*MCRIS**	*Rural Residential*	*MCRIS**
Soils	**Ingestion**	●	●	●	●
	Dermal	—	—	—	—
	External	●	●	NA	NA
Air (Dust)	**Inhalation**	●	●	—	—
	External	—	—	NA	NA
Groundwater	**Ingestion**	—	—	—	—
	Inhalation	—	—	—	—
	Dermal	—	—	—	—
	External	—	—	NA	NA
Surface Water	**Ingestion**	—	—	—	—
	Inhalation	—	—	—	—
	Dermal	—	—	—	—
	External	—	—	NA	NA
Biota	**Dairy**	│	—	—	—
	Beef	│	—	—	—
	Game	│	—	—	—
	Fish	│	—	—	—
	Plant/Crop	│	—	NA	NA

SOURCE: DOE-RL, 1993a

* **Modified CRCIA Ranger/Industrial Scenario**

NA = Not Applicable

E9608093.1

● **Primary Pathway**

│ **Indirect Pathway**

— **Pathway Not Assessed**

Table 1-14 specifies the regulatory and project constraints in relation to regulatory milestones.

Table 1-14. Regulatory Milestones.

Milestone	Due Date	Regulatory Driver
Begin remediation for 100-NR-1 TSD sites	July 2000	RCRA Sitewide permit requires that remediation for 100-NR-1 TSD sites begin not later than July 2000 and completion not later than June 2003.
Begin closure activities for 120-N-1, 120-N-2, 100-N-58, and associated pipelines	July 2001	
Complete remediation for 100-NR-1 TSD sites	June 2003	

The project milestones and regulatory drivers for this DQO process are specified in Table 1-15.

Table 1-15. Project Milestones.

Milestone	Due Date	Regulatory Driver
DQO workbook	January 2000	None
Sampling and analysis plan	March 2000	None
Field implementation	July 2000	RCRA Sitewide permit
Laboratory analyses	July 2000, through June 2003	RCRA Sitewide permit requires that remediation for 100-NR-1 TSD sites begin not later than July 2000 and completion not later than June 2003.
Data quality assessment	TBD	None
Closeout report	TBD	June 2003

TBD = to be determined

Table 1-16 provides a breakdown of cost in respect to the project budget.

Table 1-16. Project Budget.

Project Milestones	Budget
DQO workbook development	$89.4K
Sampling and analysis plan development	$46.3K
Field implementation	TBD; remediation is in the design phase, and cost estimating and budgeting will be developed at completion of design.
Laboratory analyses	TBD; remediation is in the design phase, and cost estimating and budgeting will be developed at completion of design.
Data quality assessment	N/A; will be prepared as part of site closeout effort following site remediation.
Documentation of investigation results	TBD; remediation is in the design phase, and cost estimating and budgeting will be developed at completion of design.

N/A = not applicable
TBD = to be determined

As stated above, the purpose of the project is to remediate the sites identified in the interim remedial action ROD for the 100-NR-1 TSD sites (Ecology et al. 2000). The statements in Table 1-17 are in alignment with that purpose. Additionally, a requirement of the project is to characterize the waste for disposal.

Table 1-17. Concise Statement of the Problem. (2 pages)

- Given the goal of removing soils, structures, pipelines, etc., in accordance with the interim remedial action ROD (Ecology et al. 2000) that exceed direct exposure RAOs for rural-residential exposure to a depth of 4.6 m (15 ft) below surrounding grade or to the bottom of the engineered structure (whichever is deeper), the problem is to verify that the sites meet the RAOs for rural-residential exposure of 15 mrem/yr above natural background for radionuclides and MTCA Method B values for nonradioactive contaminants.

- Given the goal of removing soils, structures, pipelines, etc., in accordance with the interim remedial action ROD to a depth of 1.5 m (5 ft) below the engineered structures of 116-N-1 and 116-N-3 units that contain plutonium-239/240 contaminants, the problem is to verify that the cleanup standards for the protection of groundwater and the Columbia River have been met for remaining soils.

- Given the goal of using overburden and layback as part of the backfill in accordance with the interim remedial action ROD, the problem is to verify that crib/trench cover contamination does not exceed the goals for rural-residential exposure and/or for protection of the Columbia River.

- Given the goal of waste characterization, the problem is to verify that radioactive and chemical constituents in the waste are compliant with the waste acceptance requirements of the facility receiving the waste.

Table 1-17. Concise Statement of the Problem. (2 pages)

- Given the goal of determining where the uncontaminated portion of the 116-N-3 Trench ends, the problem is to identify a transition zone near the first dam that meets the conditions for direct exposure and river protection without excavation (and, thereby, establish that the remainder of the 116-N-3 Trench, downstream of that transition zone, is clean).
- Given the goal of removing the liner, the pipelines (if contaminated), fence, and sampling shed at the nonradioactive sites (i.e., 120-N-1, 120-N-2, and 100-N-58), the problem is to determine if the debris meets disposal criteria.

2.0 STEP 2 -- IDENTIFY THE DECISION

2.1 PURPOSE

The purpose of DQO Step 2 is to define the principal study questions (PSQs) to be resolved using new or existing measurements. Alternative actions are identified that could result from resolution of the PSQs, and the consequences of each of the alternative actions are evaluated in this step.

The PSQs and alternative actions are combined into decision statements that state the problem and associated alternative actions. DQO Step 2 is the key step from which DQO Steps 3 through 7 shall be based; therefore, it is critical that the decision statements developed are accurate and address all of the questions needing to be resolved and support all actions that may be taken.

2.1.1 Identify the Decision

Table 2-1 identifies the PSQs that will require environmental measurements (e.g., physical, chemical, or radiological data) to resolve.

Table 2-1. Principal Study Questions.

PSQ #	Principal Study Questions
1	Do excavated contaminated soil/debris/pipelines meet ERDF waste acceptance criteria?
2	Does debris/piping from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet requirements for disposal in onsite inert/demolition waste landfills?
3	Do soils remaining after remediation meet site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan?
4	Do overburden and layback soils meet criteria for use as backfill?
5	Does imported soil from onsite borrow pits meet criteria for use as backfill?
6	Do pipelines from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet criteria for being left in place?
7	Where is the location in the 116-N-3 Trench (near the first dam) beyond which the soil and structure are clean and no remedial action is needed?

Table 2-2 identifies the alternative actions that could be taken after the PSQs have been resolved.

Table 2-2. Alternative Actions.

PSQ #	AA #	Alternative Actions
1	1	Excavated contaminated soil/debris meets ERDF waste acceptance criteria and is disposed in the ERDF.
	2	Excavated contaminated soil/debris exceeds ERDF waste acceptance criteria and cannot be disposed in the ERDF, and alternative disposal options need to be evaluated.
2	1	Debris meets criteria for disposal in onsite inert/demolition waste landfills and is disposed in onsite inert/demolition landfills.
	2	Debris exceeds criteria for disposal in onsite inert/demolition waste landfills and is not disposed in onsite inert/demolition landfills.
3	1	Soils meet criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD or CMS/closure plan and remediation efforts are ended.
	2	Soils exceed criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD or CMS/closure plan and remediation efforts are continued.
4	1	Overburden and layback soil meet criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD and are used as backfill.
	2	Overburden and layback soil exceed criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD and are disposed of as contaminated waste.
5	1	Imported soil from onsite borrow pits meets criteria for use as backfill and is used for backfill.
	2	Imported soil from onsite borrow pits exceeds criteria for use as backfill and is not used for backfill.
6	1	Pipelines meet the requirements established in the CMS/closure plan for clean sites and are left in place.
	2	Pipelines exceed the requirements established in the CMS/closure plan for clean sites and are removed.
7	1	A transition zone near the first dam is identified beyond which remedial action (excavation of contaminated soil) is not needed.
	2	A transition zone near the first dam is identified beyond which additional remedial action (excavation of contaminated soil) is needed.

AA = alternative action

The potential consequences of erroneous alternative actions are listed in Table 2-3.

Table 2-3. Consequences of Erroneous Alternative Actions. (3 pages)

DS #	AA #	Consequences	Severity (Severe/ Not Severe)	Rationale for Determining Consequence Severity
1	1	Excavated contaminated soil/debris is erroneously determined to meet the ERDF waste acceptance criteria and soil/debris that exceeds ERDF waste acceptance criteria and is disposed in the ERDF.	Moderate	The ERDF is an engineered facility with features that are protective of groundwater and direct exposure.
	2	Excavated contaminated soil/debris is erroneously determined to exceed the ERDF waste acceptance criteria and alternative disposal options are evaluated for ERDF-acceptable soil/debris.	Low	There would be an economic impact, but the action would not pose a threat to human health or the environment.
2	1	Debris from nonradioactive sites is erroneously determined to meet dangerous waste requirements and contaminated debris is disposed in an onsite inert/demolition waste landfill.	Moderate	Inert demolition landfills are fairly remote and do not pose an immediate threat to human health or the environment.
	2	Debris from nonradioactive sites is erroneously determined to exceed dangerous waste requirements and alternative disposal options are evaluated to dispose of clean debris.	Low	There would be an economic impact, but the action would not pose a threat to human health or the environment.
3	1	Residual site contamination levels are erroneously determined to meet acceptable limits and remediation efforts are ended, leaving unacceptable levels of contamination at the site.	Severe	Residual levels of contamination could pose a risk to human health or the environment.
	2	Residual site contamination levels are erroneously determined to exceed acceptable limits and remediation efforts continue to cleanup an already clean site.	Low	There would be an economic impact, but the action would not pose a threat to human health or the environment.

Table 2-3. Consequences of Erroneous Alternative Actions. (3 pages)

PSQ #	AA #	Consequences	Severity (Severe/Not Severe)	Rationale for Determining Consequence Severity
4	1	Contamination levels of overburden and layback soil are erroneously determined to be within limits acceptable for use as backfill, and contaminated overburden and layback soil are used as backfill.	Severe	Residual levels of contamination could pose a risk to human health or the environment.
	2	Contamination levels of overburden and layback soil are erroneously determined to exceed limits acceptable for use as backfill and clean overburden, and layback soil are disposed of as contaminated waste.	Low	There would be an economic impact, but the action would not pose a threat to human health or the environment.
5	1	Imported soil from onsite borrow pits is erroneously determined to meet limits acceptable for use as backfill and the site is backfilled with contaminated soil.	Low	Process history of borrow pits is such that even if contamination is present, it would be at very low levels and would not pose a significant threat to human health or the environment.
	2	Imported soil from onsite borrow pits is erroneously determined to exceed limits acceptable for use as backfill and the site is backfilled with clean soil from alternative sources.	Low	There would be an economic impact, but the action would not pose a threat to human health or the environment.
6	1	Contamination levels of pipelines associated with the 120-N-1, 120-N-2, and 100-N-58 sites are erroneously determined to meet criteria for the pipelines to be left in place, and contaminated pipelines are left in place.	Low	Contaminants of concern are such that even if some contamination is left in place, the consequences to human health and the environment are not significant.
	2	Contamination levels of pipelines associated with the 120-N-1, 120-N-2, and 100-N-58 sites are erroneously determined to exceed criteria for the pipelines to be left in place, and clean pipelines are excavated and disposed of in a landfill.	Low	There would be an economic impact, but the action would not pose a threat to human health or the environment.

Table 2-3. Consequences of Erroneous Alternative Actions. (3 pages)

PSQ #	AA #	Consequence	Severity (Severe/ Not Severe)	Rationale for Determining Consequence Severity
7	1	Contamination levels in a transition zone near the first dam are erroneously determined to meet acceptable limits and no remediation actions are taken beyond this transition zone, leaving unacceptable levels of contamination at the site.	Severe	Residual levels of contamination could pose a risk to human health or the environment.
	2	Contamination levels in a transition zone near the first dam are erroneously determined to exceed acceptable limits, and remediation actions are taken beyond this transition zone to cleanup an already clean site.	Low	There would be an economic impact, but the action would not pose a threat to human health or the environment.

The PSQs and alternative actions are turned into decision statements in Table 2-4 using the following format: *Determine whether or not [unknown environmental conditions/issues/criteria from the PSQ] require (or support) [taking alternative actions].*

Table 2-4. Decision Statements. (2 pages)

DS #	Decision Statements
1	Determine if excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3, and UPR-100-N-31) meets ERDF waste acceptance criteria (BHI 1998a) and can be disposed in the ERDF or if alternate disposal options need to be considered.
2	Determine if debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meets requirements for disposal in onsite inert/demolition waste landfills or if alternate disposal options need to be considered.
3	Determine if soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan and require additional remediation or if remedial action is complete.
4	Determine if contamination levels of overburden and layback soil exceed site criteria identified in the interim remedial action ROD meet the criteria for backfill or if the soil must be disposed in the ERDF.
5	Determine if contamination levels of borrow pit soil meet site criteria for use as backfill or if alternate backfill material must be used.

Table 2-4. Decision Statements. (2 pages)

DS #	Decision Statements
6	Determine if contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet site criteria identified in the CMS/closure plan for being left in place or if the pipelines must be removed and disposed appropriately (in the ERDF or in the inert/demolition waste landfill).
7	Determine if soils in a transition zone after the first dam in the 116-N-3 Trench exceed site cleanup criteria identified in the interim remedial action ROD and require additional remediation or if remedial action is complete.

DS = decision statement

A summary of the information contained in Tables 2-1 through 2-4 is contained in Table 2-5.

Table 2-5. Summary of DQO Step 2 Information. (4 pages)

PSQ /AA #	Principal Study Question #1 -- Do excavated contaminated soil/debris/pipelines meet ERDF waste acceptance criteria?		
	Alternative Action	Consequences	Severity of Consequences
1-1	Excavated contaminated soil/debris meets ERDF waste acceptance criteria and is disposed in the ERDF.	Excavated contaminated soil/debris is erroneously determined to meet the ERDF waste acceptance criteria and soil/debris that exceeds ERDF waste acceptance criteria is disposed in the ERDF.	Moderate
1-2	Excavated contaminated soil/debris exceeds ERDF waste acceptance criteria and cannot be disposed in the ERDF and alternative disposal options need to be evaluated.	Excavated contaminated soil/debris is erroneously determined to exceed the ERDF waste acceptance criteria and alternative disposal options are evaluated for ERDF-acceptable soil/debris.	Low
DS #1	**Decision Statement #1** -- Determine if excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3, and UPR-100-N-31) meets ERDF waste acceptance criteria and can be disposed in the ERDF or if alternate disposal options need to be considered.		
PSQ /AA #	Principal Study Question #2 -- Does debris/piping from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet requirements for disposal in onsite inert/demolition waste landfill?		
	Alternative Action	Consequences	Severity of Consequences
2-1	Debris meets criteria for disposal in onsite inert/demolition waste landfills and is disposed in onsite inert/demolition landfills.	Debris from nonradioactive sites is erroneously determined to meet dangerous waste requirements and contaminated debris is disposed in an onsite inert/demolition waste landfill.	Moderate

Table 2-5. Summary of DQO Step 2 Information. (4 pages)

2-2	Debris exceeds criteria for disposal in onsite inert/demolition waste landfills and is not disposed in onsite inert/demolition landfills.	Debris from nonradioactive sites is erroneously determined to exceed dangerous waste requirements and alternative disposal options are evaluated to dispose of clean debris.	Low
DS #2	**Decision Statement #2** -- Determine if debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meets requirements for disposal in onsite inert/demolition waste landfills or if alternate disposal options need to be considered.		
PSQ/AA #	Principal Study Question #3 -- Do soils remaining after remediation meet site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan?		
	Alternative Action	Consequences	Severity of Consequences
3-1	Soils meet criteria for protection of groundwater and direct exposure, as specified in the interim remedial action ROD or CMS/closure plan, and remediation efforts are ended.	Residual site contamination levels are erroneously determined to meet acceptable limits and remediation efforts are resulted in leaving unacceptable levels of contamination at the site.	Severe
3-2	Soils exceed criteria for protection of groundwater and direct exposure, as specified in the interim remedial action ROD or CMS/closure plan, and remediation efforts are continued.	Residual site contamination levels are erroneously determined to exceed acceptable limits and remediation efforts continue to cleanup an already clean site.	Low
DS #3	**Decision Statement #3** -- Determine if soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan and require additional remediation or if remedial action is complete.		
PSQ/AA #	Principal Study Question #4 -- Do overburden and layback soils meet criteria for use as backfill?		
	Alternative Action	Consequences	Severity of Consequences
4-1	Overburden and layback soil meet criteria for protection of groundwater and direct exposure, as specified in the interim remedial action ROD, and are used as backfill.	Contamination levels of overburden and layback soil are erroneously determined to be within limits acceptable for use as backfill, and contaminated overburden and layback soil are used as backfill.	Severe
4-2	Overburden and layback soil exceed criteria for protection of groundwater and direct exposure, as specified in the interim remedial action ROD, and are disposed of as contaminated waste.	Contamination levels of overburden and layback soil are erroneously determined to exceed limits acceptable for use as backfill, and clean overburden and layback soil are disposed of as contaminated waste.	Low

Table 2-5. Summary of DQO Step 2 Information. (4 pages)

DS #4	**Decision Statement #4 --** Determine if contamination levels of overburden and layback soil exceed site criteria identified in the interim remedial action ROD for meet criteria for backfill or if the soil must be disposed in the ERDF.		
PSQ -AA #	**Principal Study Question #5 -- Does imported soil from onsite borrow pits meet criteria for use as backfill?**		
	Alternative Action	**Consequences**	**Severity of Consequences**
5-1	Imported soil from onsite borrow pits meets criteria for use as backfill and is used for backfill.	Imported soil from onsite borrow pits is erroneously determined to meet limits acceptable for use as backfill and the site is backfilled with contaminated soil.	Low
5-2	Imported soil from onsite borrow pits exceeds criteria for use as backfill and is not used for backfill.	Imported soil from onsite borrow pits is erroneously determined to exceed limits acceptable for use as backfill and the site is backfilled with clean soil from alternative sources.	Low
DS #5	**Decision Statement #5 --** Determine if contamination levels of borrow pit soil meet site criteria identified in the interim remedial action ROD for use as backfill or if alternate backfill material must be used.		
PSQ -AA #	**Principal Study Question #6 -- Do pipelines from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet criteria for being left in place?**		
	Alternative Action	**Consequences**	**Severity of Consequences**
6-1	Pipelines meet the requirements established in the CMS/closure plan for clean sites and are left in place.	Contamination levels of pipelines associated with the 120-N-1, 120-N-2, and 100-N-58 sites are erroneously determined to meet criteria for the pipelines to be left in place and contaminated pipelines are left in place.	Low
6-2	Pipelines exceed the requirements established in the CMS/closure plan for clean sites and are removed.	Contamination levels of pipelines associated with the 120-N-1, 120-N-2, and 100-N-58 sites are erroneously determined to exceed criteria for the pipelines to be left and clean pipelines are excavated and disposed of in a landfill.	Low
DS #6	**Decision Statement #6 --** Determine if contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet site criteria identified in the CMS/closure plan for being left in place or if the pipelines must be removed and disposed appropriately (ERDF or inert/demolition waste landfill).		

Table 2-5. Summary of DQO Step 2 Information. (4 pages)

PSQ #/ AA #	Principal Study Question #7 -- Where is the location in the 116-N-3 Trench (near the first dam) beyond which the soil and structure are clean and no remedial action is needed?		
	Alternative Action	**Consequences**	**Severity of Consequences**
7-2	A transition zone near the first dam is identified beyond which remedial action (excavation of contaminated soil) is not needed.	Contamination levels in a transition zone near the first dam are erroneously determined to meet acceptable limits and no remediation actions are taken beyond this transition zone leaving unacceptable levels of contamination at the site.	Severe
7-2	A transition zone near the first dam is identified beyond which additional remedial action (excavation of contaminated soil) is needed.	Contamination levels in a transition zone near the first dam are erroneously determined to exceed acceptable limits and remediation actions are taken beyond this transition zone to cleanup an already clean site.	Low
DS #7	**Decision Statement #7** -- Determine if soils in a transition zone after the first dam in the 116-N-3 Trench exceed site cleanup criteria identified in the interim remedial action ROD and require additional remediation or if remedial action is complete.		

3.0 STEP 3 – IDENTIFY INPUTS TO THE DECISION

3.1 PURPOSE

The purpose of DQO Step 3 is to identify the informational inputs that will be required to resolve PSQs and determine which inputs require environmental measurements, model computations, and/or sampling.

3.2 WORKSHEETS FOR STEP 3 – IDENTIFY THE INPUTS TO THE DECISION

Table 3-1 defines the informational needs, data requirements, and data acquisition methods for this DQO process.

Table 3-1. Informational Needs, Data Requirements, and Data Acquisition Methods. (2 pages)

PSQ #	Environmental Variable Informational Need	Type of Data Required	Computational Methods that Satisfy the Informational Need	Survey/Sampling Methods that Satisfy Informational Need
1	Chemical and radiochemical	Alpha, beta, and gamma isotopic concentrations and toxicity characteristic determination for metals in soils, sediments, and exposed surfaces of concrete and piping.	Correlation of analytical data with field surveys of radionuclides.	Field measurements with limited analytical laboratory confirmation.
2	Chemical	Toxicity characteristic determination for metals in exposed surfaces of debris.	Direct comparison to dangerous waste limits.	Analytical laboratory confirmation.
3	Chemical and radiochemical	Chemical and radiochemical concentrations in soil and sediments.	Calculate direct exposure and impact to vadose zone, groundwater and Columbia River using the RESRAD model.	Analytical laboratory determination of radionuclide concentrations in soils followed by calculation of impact to the vadose zone, groundwater, and the Columbia River using the RESRAD model.

Table 3-1. Informational Needs, Data Requirements, and Data Acquisition Methods. (2 pages)

PSQ #	Environmental Variable Informational Need	Type of Data Required	Computational Methods that Satisfy the Informational Need	Survey/Sampling Methods that Satisfy Informational Need
4	Chemical and radiochemical	Chemical and radiochemical concentrations in overburden and layback soil.	Calculate direct exposure and impact to vadose zone, groundwater, and Columbia River using the RESRAD model.	Analytical laboratory determination of radionuclide concentrations in soils followed by calculation of impact to the vadose zone, groundwater, and the Columbia River using the RESRAD model.
5	Radiochemical	Field screening surveys.	None.	Historical knowledge and field surveys.
6	Chemical	Contamination levels in exposed surfaces of pipelines.	Direct comparison to dangerous waste limits.	Analytical laboratory confirmation.
7	Chemical and radiochemical	Chemical and radiochemical concentrations in soil.	Calculate direct exposure and impact to vadose zone, groundwater and Columbia River using the RESRAD model.	Analytical laboratory determination of radionuclide concentrations in soils followed by calculation of impact to the vadose zone, groundwater, and the Columbia River using the RESRAD model.

Table 3-2 lists the potential computation methods.

Table 3-2. List of Potential Computational Methods.

PSQ #	Computational Method	Source/Author	Application to Study (Rationale for Use)	Satisfy Input Req't?
1	Direct comparison of analytical data with field surveys	See calculation in Appendix A	Residual radioactive material in the waste sites will cause high background radiation. This will make it difficult to provide real-time analysis of the waste unless the radioactivity from the waste can be tied to the dose rates detected in the waste.	Yes
2, 5, and 6	None	N/A	N/A	N/A
3, 4, and 7	RESRAD	*Manual for Implementing Residual Radioactive Material Guidelines*, ANL/EAD/LD-2 (ANL 1993)	Analytical laboratory determination of chemical and radionuclide concentrations in soils, surfaces of concrete and pipes, followed by calculation of impact to vadose zone soils, groundwater, and Columbia River using the RESRAD model.	Yes

N/A = not applicable

Table 3-3 identifies the type of information needed to perform a quantitative assessment for the alternative actions identified in DQO Step 2 as having severe decision error consequences.

Table 3-3. Required Information for Quantitative Assessment. (2 pages)

PSQ # / AA #	Required Information to Assess Impact		
	Cost	Risk	
		Human Health	Ecological
1-1	Moderate	Moderate	Moderate
1-2	High	Low	Low
2-1	Low	Moderate	Moderate
2-2	Low	Low	Low
3-1	Low	Severe	Severe
3-2	Moderate	Low	Low
4-1	Low	Severe	Severe
4-2	Moderate	Low	Low
5-1	Low	Low	Low

Table 3-3. Required Information for Quantitative Assessment. (2 pages)

PSQ # AA #	Required Information to Assess Impact		
	Cost	Risk	
		Human Health	Ecological
5-2	Moderate	Low	Low
6-1	Low	Low	Low
6-2	High	Low	Low
7-1	Moderate	Severe	Severe
7-2	Moderate	Low	Low

The sources for the information needed to resolve the PSQs are identified in Table 3-4 (e.g., previous data collection efforts, historical records, regulatory guidance, professional judgment, scientific literature, new data collections, and engineering standards). Existing appropriate data will be evaluated quantitatively in DQO Step 7.

Table 3-4. Required Information and Reference Sources. (2 pages)

PSQ #	Required Information	Do Data Exist? (Y/N)	Source Reference	Sufficient Quality (Y/N)	Add'l Data Req'd (Y/N)
1	Alpha, beta, and gamma isotopic concentrations and toxicity characteristic determination for metals in soils, sediments, and exposed surfaces of concrete and piping	Y	Data summary report (BHI 1999c)	N	Y
2	Chemical data from debris	N		N	Y
3	Chemical and radiochemical concentrations in soil and sediments remaining after excavation	N		N	Y
4	Chemical and radiochemical concentrations in overburden and layback soil	N		N	Y

Table 3-4. Required Information and Reference Sources. (2 pages)

PSQ #	Required Information	Do Data Exist? (Y/N)	Source Reference	Sufficient Quality (Y/N)	Add'l Data Req'd (Y/N)
5	Chemical and radiochemical concentrations in soil	Y	Process history/knowledge	N	Y
6	Chemical concentrations in exposed surfaces of pipelines	N		N	Y
7	Chemical and radiochemical concentrations in soil	N		N	Y

The following information is contained in Table 3-5:

- Identification of the information needed to establish the action levels.
- Definition of the preliminary action levels (see DQO Step 1, Table 1-11, which summarizes the site-specific ARARs).
- Definition of the basis for setting the action levels. The action level is the threshold value that provides the criterion for choosing between alternative actions. Action levels may be based on regulatory thresholds or standards, or the levels may be derived from problem-specific considerations such as risk analysis. The actual numerical action level will be set in DQO Step 5.

Table 3-5. Basis for Setting Preliminary Action Levels. (4 pages)

DS #	Media	COCs	Preliminary Action Level	Basis
		Radionuclides	*(pCi/g)*	
1	Soil, concrete structures, and pipelines	Americium-241	25,500	*Environmental Restoration Disposal Facility Waste Acceptance Criteria* (BHI 1998a) radionuclide limits are based on a soil density of 1.96 metric ton/m^3.
		Cesium-137	16,300,000	
		Cobalt-60	No limit	
		Europium-154	No limit	
		Europium-155	No limit	
		Nickel-63	3.57E+08	
		Plutonium-238	765,000	
		Plutonium-239/240	14,000	
		Strontium-90	3.6E+09	
		Tritium	No limit	
		Uranium-233/234	37,700	
		Uranium-235	1,300	
		Uranium-238+dau	6,100	

Table 3-5. Basis for Setting Preliminary Action Levels. (4 pages)

DS	Media	COCs	Preliminary Action Level	Basis
		Metals (mg/kg)		
		Antimony	19,000	
		Arsenic	3,000	
		Barium	940,000	
		Cadmium	39,000	
		Chromium (total)	59,000	
		Chromium (VI)	59,000	
		Lead	No limit	
		Manganese	440,000	
		Nickel	No limit	
		Selenium	400,000	
		Silver	350,000	
		Vanadium	330,000	
		Zinc	300,000	
		Mercury	No limit	
		Nitrate	No limit	
		pH (pH units)	<2 or >12.5	
		Sulfate	No limit	
		TCLP (mg/L)		
		Arsenic	5	
		Barium	100	
		Cadmium	1	
		Chromium (total)	5	
		Lead	5	
		Selenium	5.7	
		Silver	5	
		Mercury	0.2	
2	Soil, liner, and concrete from 120-N-1, 120-N-2, 100-N-58, and associated pipelines	**TCLP (mg/L)**		WAC 173-303-090
		Arsenic	5	
		Barium	100	
		Cadmium	1	
		Chromium (total)	5	
		Lead	5	
		Mercury	0.2	
		Selenium	1	
		Silver	5	
		pH (pH units)	<2 or >12.5	

Table 3-5. Basis for Setting Preliminary Action Levels. (4 pages)

DS	Media	[illegible]	Preliminary Action Level	Basis
3,4, 5, and 7	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines radiological sites	Radionuclides (pCi/g)		Values for radionuclides from the interim remedial action ROD (Ecology et al. 2000). Values for americium-241 and nickel-63 are not included in the interim remedial action ROD but were calculated using RESRAD (ANL 1993) and represent the 15 mrem/yr limit (surface soil).
		Americium-241	41.6	
		Cesium-137	6.1	
		Cobalt-60	1.4	
		Europium-154	3.1	
		Europium-155	127	
		Nickel-63	4,031	
		Plutonium-239/240	23.5	
		Strontium-90	3.7	
		Tritium	241	
		Inorganics (mg/kg)		MTCA Method B
		Chromium (VI)	400	
		Mercury	24	
		Nitrate	113,000	
	Subsurface (>4.6 m [>15 ft] bgs) soil, concrete structures, and pipelines radiological sites	Radionuclides (pCi/g)		Values for radionuclides from the interim remedial action ROD (Ecology et al. 2000). Americium-241, nickel-63, and strontium-90 are not calculated to reach groundwater within a 1,000-year time frame.
		Americium-241	N/A	
		Nickel-63	N/A	
		Plutonium-239/240	N/A	
		Strontium-90	N/A	
		Tritium	2,000	
		Inorganics (mg/kg)		Values for inorganics from the interim remedial action ROD (Ecology et al. 2000). Mercury is not calculated to reach groundwater within a 1,000-year time frame.
		Chromium (VI)	2	
		Mercury	N/A	
		Nitrate	4,400	

Table 3-5. Basis for Setting Preliminary Action Levels. (4 pages)

DS#	Media	COC	Preliminary Action Level	Basis
		Inorganics (mg/kg)		
3 and 6	120-N-1, 120-N-2, 100-N-58 soil, and associated pipelines	Antimony	32	Data are MTCA Method B values, unless otherwise indicated.
		Arsenic	20[a]	
		Barium	5,600	
		Beryllium	400	
		Chromium (VI)	400	
		Copper	2,960	
		Lead	353[b]	
		Manganese	11,200	
		Mercury	24	
		Nickel	1,600	
		Selenium	400	
		Sulfate	25,000[c]	
		Thallium	6	
		Vanadium	560	
		Zinc	24,000	

[a] Arsenic limits are from MTCA Method A due to high background values per discussions with regulators.
[b] MTCA Method B value for lead is not available. This value is based on EPA's *Integrated Exposure Uptake Biokinetic Model for Lead in Children* (EPA 1994a).
[c] Based on 100 times the PRG for groundwater/Columbia River protection.
N/A = not applicable
TCLP = toxicity characteristic leachate procedure

Table 3-6 lists the information needed to perform the DQO Step 6 quantitative assessment of the alternative actions identified in DQO Step 2 with severe decision error consequences. This information should evaluate the impact to cost, risk to human health and the environment, and schedule.

Table 3-6. Quantitative Assessment of Decision Error Consequences. (2 pages)

PSQ /AA #	Consequences of Decision Error			
	Incremental Cost Above Project Baseline	Human Health Risk	Environmental Risk	Schedule
1-1	Moderate	Moderate	Moderate	July 2000 through June 2003
1-2	High	Low	Low	July 2000 through June 2003
2-1	Low	Moderate	Moderate	July 2000 through June 2003
2-2	Low	Low	Low	July 2000 through June 2003
3-1	Low	Severe	Severe	July 2000 through June 2003
3-2	Moderate	Low	Low	July 2000 through June 2003

Table 3-6. Quantitative Assessment of Decision Error Consequences. (2 pages)

PSQ/A #	Consequences of Decision Error			
	Incremental Cost Above Project Baseline	Human Health Risk	Environmental Risk	Schedule
4-1	Low	Severe	Severe	July 2000 through June 2003
4-2	Moderate	Low	Low	July 2000 through June 2003
5-1	Low	Low	Low	July 2000 through June 2003
5-2	Moderate	Low	Low	July 2000 through June 2003
6-1	Low	Low	Low	July 2000 through June 2003
6-2	High	Low	Low	July 2000 through June 2003
7-1	Moderate	Severe	Severe	July 2000 through June 2003
7-2	Moderate	Low	Low	July 2000 through June 2003

It is essential to confirm that appropriate measurement methods exist to provide the necessary data. It should be noted that the consequences of decision error (in DQO Step 6) will determine the level of analysis required (e.g., field screening or fixed laboratory). Table 3-7 develops a list of potentially appropriate measurement methods.

Table 3-7. Appropriate Measurement Methods.

WS #	Media	Environmental Variable	Potentially Appropriate Measurement Method[a]	Possible Limitations or Reservations
1 and 5	All	Screening concentration	Field instruments (e.g., NaI, XRF, and soil gas analyzer); radiation counting facilities; quick turnaround laboratories (HPGe)	Background radiation levels are relatively high in these areas. Detection limits not as low as remediation goals (to 15 mrem/yr or MTCA Method B) and may not detect low levels that could also require remediation.
All	All	Verification sampling concentration	Standard fixed laboratory methods (e.g., AEA, GeLi, HPGe, and EPA Methods 6010 or 7471)	Cost and turnaround time.

[a] Other methods may be identified and implemented in conjunction with technology development.
AEA = alpha energy analysis
GeLi = germanium-lithium
HPGe = high-purity germanium
NaI = sodium iodide
XRF = x-ray fluorescence

The method detection limit, action level, limit of quantitation, precision, and accuracy requirements for each potential method are identified in Table 3-8.

Table 3-8. Analytical Performance Requirements. (4 pages)

Data Type	Analytical Method	Analyte	Data Use	Preliminary Action Level	Detection Limit Requirements		Accuracy Req't (% Recovery)	Precision Req't (%RSD or RSD)
					MDL	PQL		
[illegible] Laboratory Measurements								
Radio-isotopes[a]	Chemical separation - alpha energy analysis	Americium-241	Disposal Cleanup, shallow Cleanup, deep	25,500 41.6 N/A	0.1	1	70-130	±30
	Gamma energy analysis	Cesium-137	Disposal Cleanup, shallow Cleanup, deep	16,300,000 6.1 N/A	0.05	0.1	80-120	±30
		Cobalt-60	Disposal Cleanup, shallow Cleanup, deep	No limit 1.4 N/A	0.02	0.05	80-120	±30
		Europium-154	Disposal Cleanup, shallow Cleanup, deep	No limit 3.1 N/A	0.1	0.1	80-120	±30
		Europium-155	Disposal Cleanup, shallow Cleanup, deep	No limit 127 N/A	0.2	0.1	80-120	±30
	Chemical separation - alpha energy analysis	Plutonium-239/240	Disposal Cleanup, shallow Cleanup, deep	14,000 23.5 N/A	0.1	1	70-130	±30
	Chemical separation - gas proportional	Nickel-63	Disposal Cleanup, shallow Cleanup, deep	3.57E+08 4,031 50	5	30	70-130	±30
		Strontium-90	Disposal Cleanup, shallow Cleanup, deep	3.6E+9 3.7 706	0.2	1	70-130	±30
	Chemical separation - liquid scintillation	Tritium	Disposal Cleanup, shallow Cleanup, deep	No limit 241 2,000	5	400	70-130	±30

Table 3-8. Analytical Performance Requirements. (4 pages)

Data Type	Analytical Method	Analyte	Data Use	Preliminary Action Level[a]	Detection Limit Requirements		Accuracy Req't (% Recovery)[b]	Precision Req't (%RSD or RSD)
					MDL[a]	PQL[a]		
Chemical[b]	Total metals by SW-846 Method 6010 – ICP Lower detection limit [in brackets] by trace technology TCLP analysis (in parenthesis) by SW-846 Method 1311, extraction – Method 6010 - ICP	Antimony	Disposal Cleanup, shallow Cleanup, deep	No limit 32 N/A	2	6	70-130	±30
		Arsenic	Disposal Cleanup, shallow Cleanup, deep	3,000 (5) 20[c] N/A	3 (0.02)	10 (0.1)	70-130	±30
		Barium	Disposal Cleanup, shallow Cleanup, deep	940,000 (100) 5,600 N/A	2 (0.05)	20 (0.20)	70-130	±30
		Beryllium	Disposal Cleanup, shallow Cleanup, deep	No limit 400 N/A	0.2	0.5	70-130	±30
		Cadmium	Disposal Cleanup, shallow Cleanup, deep	39,000 (1) 80 N/A	0.2 (0.003)	0.5 (0.005)	70-130	±30
		Chromium (total)	Disposal Cleanup, shallow Cleanup, deep	59,000 (5) 80,000 N/A	0.4 (0.005)	1 (0.01)	70-130	±30
		Copper	Disposal Cleanup, shallow Cleanup, deep	No limit 2,960 N/A	0.5	2.5	70-130	±30
		Lead	Disposal Cleanup, shallow Cleanup, deep	No limit (5) 353 N/A	3 (0.04)	10 (0.1)	70-130	±30
		Manganese	Disposal Cleanup, shallow Cleanup, deep	No limit 11,200 N/A	0.4	1.5	70-130	±30
		Nickel	Disposal Cleanup, shallow Cleanup, deep	No limit 1,600 N/A	1	4	70-130	±30
		Selenium	Disposal Cleanup, shallow Cleanup, deep	400,000(1) 400 N/A	5 (0.05)	10 (0.1)	70-130	±30

Table 3-8. Analytical Performance Requirements. (4 pages)

Data Type	Analytical Method	Analyte	Data Use	Preliminary Action Level[a]	Detection Limit Requirements		Accuracy Req't (% Recovery)[b]	Precision Req't (%RSD or RSD)
					MDL[a]	PQL[a]		
		Silver	Disposal Cleanup, shallow Cleanup, deep	350,000(5) 400 N/A	0.5 (0.005)	2 (0.02)	70-130	±30
		Thallium	Disposal Cleanup, shallow Cleanup, deep	No limit 5.6 N/A	4	10 [1]	70-130	±30
		Vanadium	Disposal Cleanup, shallow Cleanup, deep	No limit 560 N/A	2	5	70-130	±30
		Zinc	Disposal Cleanup, shallow Cleanup, deep	No limit 24,000 N/A	0.5	2	70-130	±30
	Total Hg by SW-846 Method 7471 – CVAA. TCLP analysis (in parenthesis) by SW-846 Method 1311, extraction – Method 7470 - CVAA	Mercury	Disposal Cleanup, shallow Cleanup, deep	No limit (0.2) 24 24	0.02 (0.001)	0.2 (0.001)	70-130	±30
	SW-846 Method 7196	Chromium (VI)	Disposal Cleanup, shallow Cleanup, deep	59,000 400 400	0.4	0.5	70-130	±30
	EPA Method 353/300	Nitrate plus nitrite as nitrogen	Disposal Cleanup, shallow Cleanup, deep	No limit 113,000 4,400	0.2	0.75	70-130	±30

Table 3-8. Analytical Performance Requirements. (4 pages)

Data Type	Analytical Method	Analyte	Data Use	Preliminary Action Level[a]	Detection Limit Requirements		Accuracy Req't (% Recovery)[b]	Precision Req't (%RSD or RSD)
					MDL[a]	PQL[a]		
	SW-846 Method 9045	pH (pH units)	Disposal Cleanup, shallow Cleanup, deep	<2 or >12.5 <2 or >12.5 N/A	0.5	0.1	NA	NA
	SW-846 Method 9056	Sulfate	Disposal Cleanup, shallow Cleanup, deep	No limit N/A N/A	2	5	70-130	±30
Performance Requirements for Field Measurements								
Radio-isotopes[a]	Portable NaI detector	Gross Cs-137 counts	Disposal Cleanup, shallow Cleanup, deep	44,900[d] 6.1 N/A	100[e]	N/A	±80-120	±20

[a] Radioisotopes measured in pCi/g.
[b] Inorganics/metals measured in mg/kg; TCLP measured in mg/L.
[c] Arsenic limits are from MTCA Method A due to high background values per discussions with regulators.
[d] Per ERDF hazard classification basis concentrations.
[e] This is based on (1) 2x2 NaI detector with a 300-kev window (lower energy cut-off), (2) a 500 count per minute background, (3) a 5-minute background count, (4) a 1-minute sample count, (5) 1% efficiency for cesium-137, and (6) a sample size of 800 g soil (or a 500-mL Marinelli beaker with a sample density of 1.6 g/cm^3).

CVAA = cold vapor atomic absorption
ICP = inductively coupled plasma
MDL = minimum detectable level
N/A = not applicable

4.0 STEP 4 -- DEFINE THE BOUNDARIES OF THE STUDY

4.1 PURPOSE

The primary objective of DQO Step 4 is for the DQO Team to identify the spatial, temporal, and practical constraints on the sampling design and consider the consequences. This objective (in terms of the spatial, temporal, and practical constraints) is to ensure that the sampling design results in the collection of data that accurately reflect the true condition of the site and/or populations being studied.

4.2 WORKSHEETS FOR STEP 4 -- DEFINE THE BOUNDARIES OF THE STUDY

Table 4-1 defines the spatial and temporal boundaries of the study to clarify what the samples are intended to represent. The characteristics that define the population of interest are also identified.

Table 4-1. Characteristics that Define the Population of Interest.

DS #	WS #	Population of Interest	Characteristics	Unit Measurement Size	Total Number of Potential Measurement Units Within the Population
1 - 7	1	116-N-1 Crib and associated pipelines, and UPR-100-N-31	Radioactivity levels, TCLP results	1 L	1.4E+10
1 - 7	2	116-N-1 Trench and cover panels	Radioactivity levels, TCLP results	1 L	1.3E+10
1 - 7	3	116-N-3 Crib, Trench, cover panels, and associated pipelines	Radioactivity levels, TCLP results	1 L	1.7E+10
1 - 7	4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	Metals, sulfate, pH, and nitrate results	1 L	1.0E+10

Table 4-2 defines the spatial boundaries of the decision and the domain or geographic area (or volume) within which all decisions must apply (in some cases, this may be defined by the operable unit). The domain is a region distinctly marked by physical features (i.e., volume, length, width, and boundary). Refer to Figure 1-1 for a map of the area.

Table 4-2. Geographic Areas of Investigation.

DS #	Geographic Areas of Investigation
1	Excavated contaminated soil from the 116-N-1 Crib and Trench, UPR-100-N-31, 116-N-3 Crib and Trench, and associated pipelines.
2	Debris (liner and other debris that contacted liquid effluents) from the 120-N-1, 120-N-2, and 100-N-58 percolation pond system.
3	Surfaces of the 116-N-1 Crib and Trench, UPR-100-N-31, 116-N-3 Crib and Trench, and northern part of 120-N-1, 120-N-2, and 100-N-58 percolation pond system as specified in the CMS/closure plan.
4	Overburden/layback piles from the 116-N-1 Crib and Trench, UPR-100-N-31, and 116-N-3 Crib and Trench.
5	Exposed surface of borrow pit sites used as a source for backfill.
6	Pipelines associated with the 120-N-1, 120-N-2, and 100-N-58 percolation pond system.
7	The floor of the 116-N-3 Trench in roughly 10 m (30 ft) in length downstream of the first dam.

When appropriate, the population is divided into strata that have relatively homogeneous characteristics. The DQO team must systematically evaluate process knowledge, historical data, and plant configurations to present evidence of a logic that supports alignment of the population into strata with homogeneous characteristics. Table 4-3 identifies the strata with homogeneous characteristics. Figures 4-1 and 4-2 provide graphical representations of these strata.

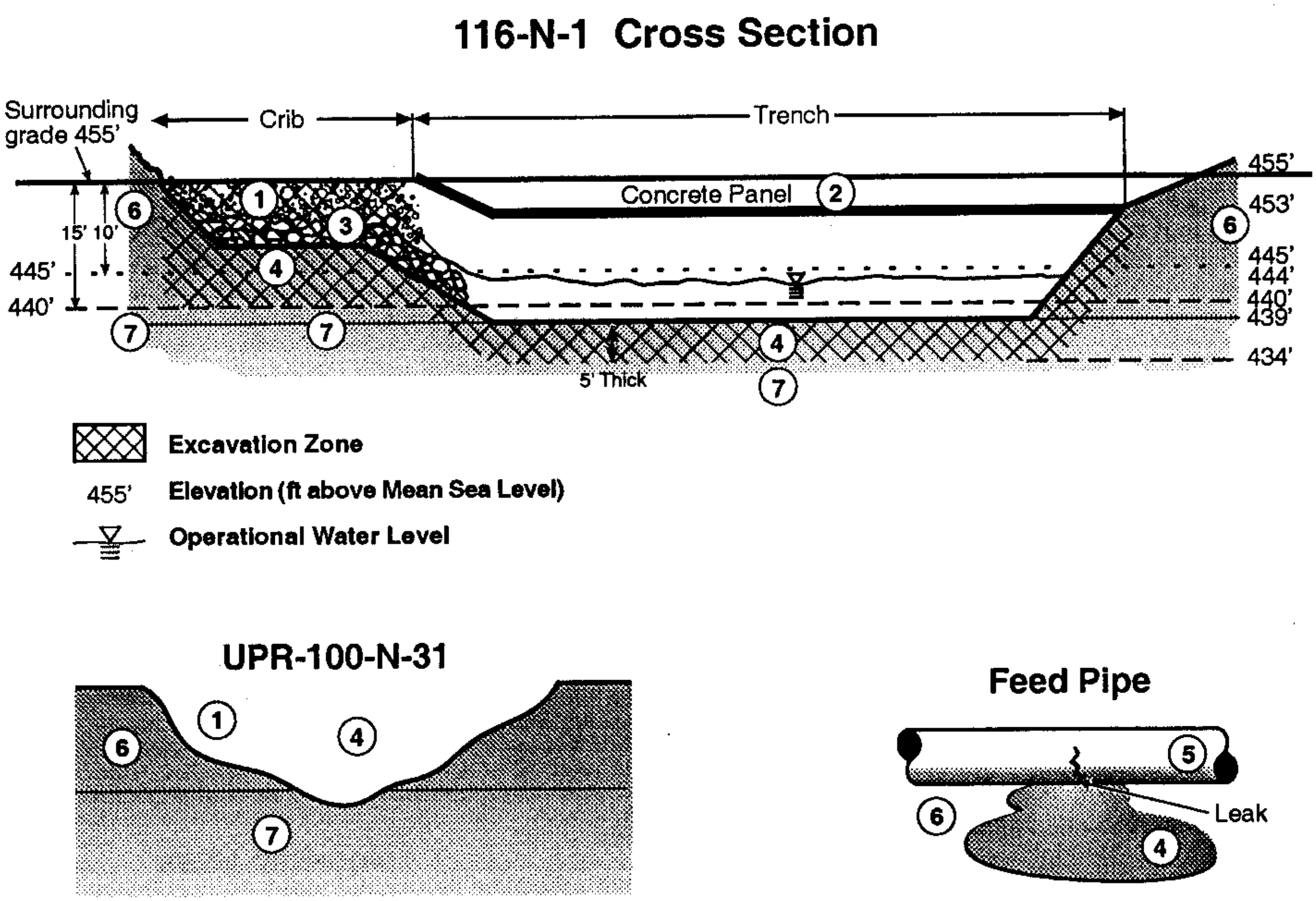
Table 4-3. Strata with Homogeneous Characteristics. (2 pages)

DS #	Decision Statement	WS #	Geographical Area of Interest	Strata	Homogeneous Characteristic Logic
1	Determine if excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3 and UPR-100-N-31) meets ERDF waste acceptance criteria and can be disposed in the ERDF or if alternate disposal options need to be considered.	1	116-N-1 Crib and associated pipelines	• Layer of contaminated boulders and cobbles • Contaminated native soil • Contaminated pipelines/debris	Each stratum was exposed to the same process.
		1	UPR-100-N-31	• Contaminated native soil	
		2	116-N-1 Trench and cover panels	• Cover panels • Contaminated native soil	
		3	116-N-3 Crib and Trench, cover panels, and associated pipelines	• Cover panels • Contaminated native soil • Contaminated pipelines/debris	
		4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	• Liner • Pipelines • Debris • Soil remaining after excavation	
3	Determine if soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD and require additional remediation or if remedial action is complete.	1	116-N-1 Crib and associated pipelines	• Surface soil remaining after excavation • Subsurface soil remaining after excavation	Each stratum was exposed to the same process.
		1	UPR-100-N-31	• Surface soil remaining after excavation • Subsurface soil remaining after excavation	
		2	116-N-1 Trench and cover panels	• Surface soil remaining after excavation • Subsurface soil remaining after excavation	
		3	116-N-3 Crib and Trench, cover panels, and associated pipelines	• Surface soil remaining after excavation • Subsurface soil remaining after excavation	
		4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	• Soil remaining at nonradioactive contaminated sites	
4	Determine if contamination levels of overburden and layback soil exceed site criteria identified in the interim remedial action ROD for meet criteria for backfill or if the soil must be disposed in the ERDF.	1	116-N-1 Crib and associated pipelines	• Overburden/layback soils	Each stratum was exposed to the same process.
		1	UPR-100-N-31	• Overburden/layback soils	
		2	116-N-1 Trench and cover panels	• Overburden/layback soils • Cover panels	
		3	116-N-3 Crib and Trench, cover panels, and associated pipelines	• Overburden/layback soils • Cover panels	
		4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	• None	

Table 4-3. Strata with Homogeneous Characteristics. (2 pages)

DS #	Decision Statement	WS #	Geographical Area of Interest	Strata	Homogeneous Characteristic Logic
5	Determine if contamination levels of borrow pit soil meet site criteria identified in the interim remedial action ROD for use as backfill or if alternate backfill material must be used.	1, 2, 3, and 4	116-N-1 Crib, Trench, cover panels, and associated pipelines; UPR-100-N-31; 116-N-3 Crib and Trench, cover panels, and associated pipelines; and 120-N-1, 120-N-2, 100-N-58, and associated pipelines	• Borrow pit soil	Borrow pits are in areas that were never exposed to radioactive contaminants.
6	Determine if contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet site criteria identified in the CMS/closure plan for being left in place or the pipelines must be removed and disposed appropriately (ERDF or inert/demolition waste landfill).	4	120-N-1, 120-N-2, and 100-N-58 associated pipelines	• Pipelines	Pipelines were exposed to the same process.
7	Determine if soils in a transition zone after the first dam in the 116-N-3 Trench exceed site cleanup criteria identified in the interim remedial action ROD and require additional remediation or if remedial action is complete.	3	116-N-3 Crib and Trench, cover panels, and associated pipelines	• Subsurface soil	Each stratum was exposed to the same process.

Figure 4-1. Strata Associated with the 116-N-1 and UPR-100-N-31 Sites.

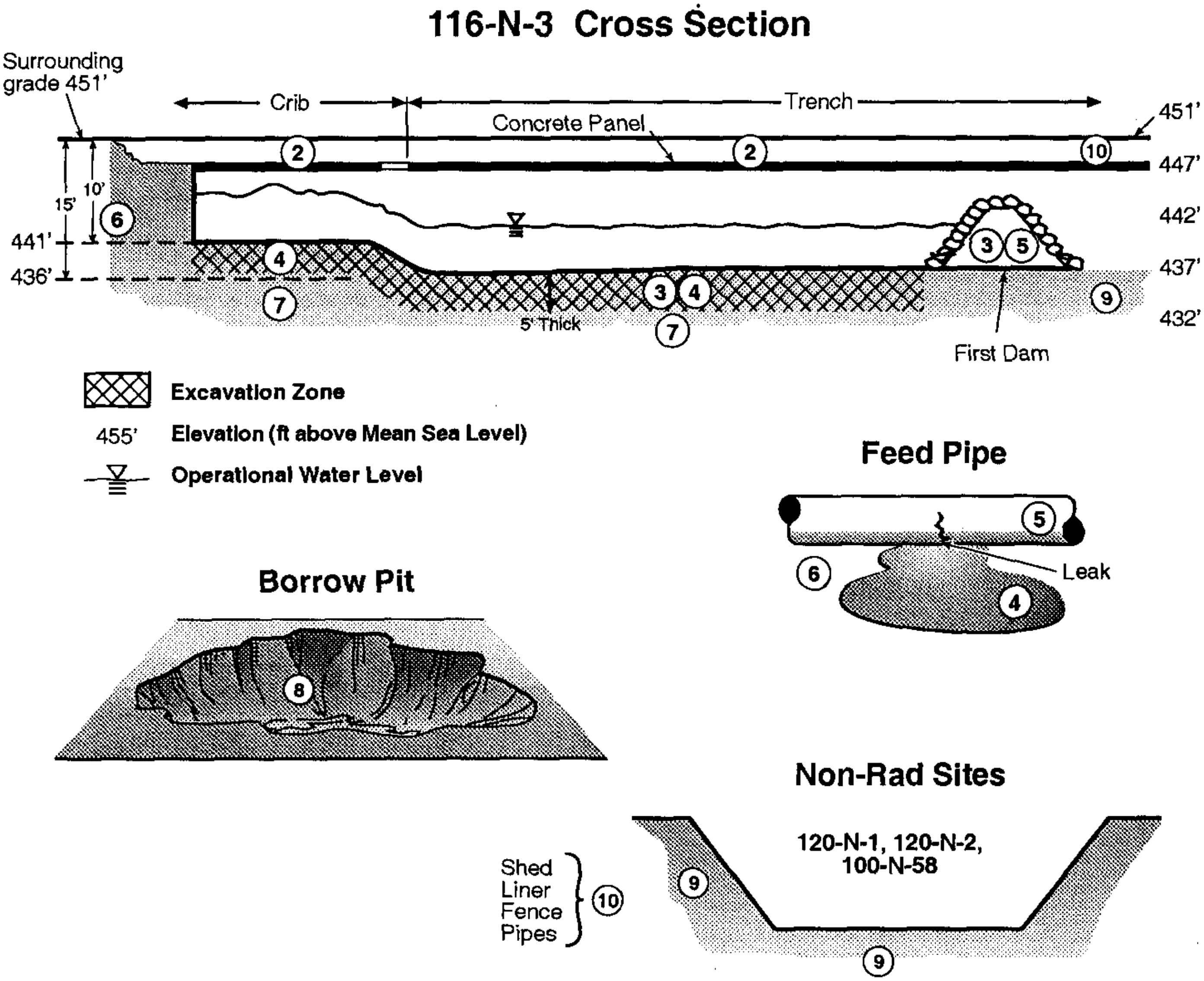


Key

1	Overburden/layback soils
2	Potentially contaminated cover panels
3	Excavated boulders and cobbles
4	Excavated native soil
5	Excavated pipe/debris
6	Surface soil remaining after excavation, rad sites
7	Suburface soil remaining after excavation, rad sites
8	Borrow pit soil
9	Soil remaining at non-rad contaminated sites
10	Debris removed from non-rad contaminated sites

E9912070.1

Figure 4-2. Strata Associated with the 116-N-3 and Nonradioactive Sites and Borrow Pits.



Key

1. **Overburden/layback soils**
2. **Potentially contaminated cover panels**
3. **Excavated boulders and cobbles**
4. **Excavated native soil**
5. **Excavated pipe/debris**
6. **Surface soil remaining after excavation, rad sites**
7. **Suburface soil remaining after excavation, rad sites**
8. **Borrow pit Soil**
9. **Soil remaining at non-rad contaminated sites**
10. **Debris removed from non-rad contaminated sites**

E9912070.2

Table 4-4 defines the spatial scale of decision making (defines each decision unit that is the smallest area or volumetric unit for which each decision applies). Decision units may be remediation units or risk units.

Table 4-4. Spatial Scale of Decision Making.

DS #	Spatial Scale of Decision Making
1	Each ERDF roll-on/roll-off container load of contaminated waste.
2	Volume of each waste stratum sent to inert/demolition landfill.
3	Shallow zone: Excavation exposed surface area 0 to 4.6 m (0 to 15 ft) bgs. Deep zone: Excavation exposed surface area deeper than 4.6 m (15 ft) bgs.
4	Volume of excavated overburden/layback from each waste site.
5	Exposed surface area of soil at each borrow pit to be used as backfill.
6	Interior surfaces of pipelines.
7	A transition zone of the floor of the 116-N-3 Trench approximately 10-m (30-ft) long.

The temporal boundaries of the decision are defined in Tables 4-5 and 4-5a.

Table 4-5. Sampling Time Frame and Sampling Design Rigor Requirements.

DS #	Time Frame	Qualitative Consequences of Inadequate Sampling Design	Resampling Access After Remedial/Disposal Actions	Required Sampling Design Rigor
1	During remediation (July 2000 to June 2003)	Not severe	Not accessible	Moderate
2	During remediation (July 2000 to June 2003)	Not severe	Not accessible	Moderate
3	At completion of remediation (approximately July 2003)	Severe	Accessible	Robust
4	During remediation (July 2000 to June 2003)	Severe	Accessible	Robust
5	Before backfill (approximately July 2003)	Not severe	Accessible	Low
6	During remediation (July 2000 to June 2003)	Not Severe	Accessible	Moderate
7	During remediation (July 2000 to June 2003)	Severe	Accessible	Robust

Table 4-5a. Consequences, Resampling Access, and Sampling Design Rigor Requirements.

Consequences of Actions	Resampling Access After Remedial Actions	Sampling Design Rigor Requirement
Severe	Inaccessible	Very robust
Severe	Accessible	Robust
Not severe	Inaccessible	Moderate
Not severe	Accessible	Low

Table 4-6 identifies measurement objectives, conditions, and constraints in relation to when data will be collected.

Table 4-6. When to Collect Data.

Measurement	Measurement Objective	Conditions	Measurement/ Condition Constraints (Time Units)
Chemical and radiochemical data	Assess levels of contaminants in soil, concrete, and pipelines	Dry weather	None

A temporal scale of decision making may be necessary for certain types of studies. For example, to regulate water quality it would be useful to set a scale of decision making that limits the time between sampling events, which would minimize the potential adverse effects in case the water quality was degraded between sampling events. The temporal scale of decision making is defined in Table 4-7.

Table 4-7. Temporal Scale of Decision Making.

DS #	Temporal Scale of Decision Making
1	During remediation.
2	During remediation.
3	After remediation but before backfill.
4	After remediation but before backfill.
5	Before backfill.
6	During remediation.
7	After remediation but before backfill.

The practical constraints on data collection are listed in Table 4-8.

Table 4-8. Practical Constraints on Data Collection.

• Sites may require sampling in areas of high radiological exposure, and the stay-time of samplers may be limited.
• High background levels of radiation may saturate field instruments.
• Difficult sample matrices (e.g., concrete, metals, and boulders) are present and may require special sample collection methods.
• Side slopes may make access by personnel and equipment difficult.

5.0 STEP 5 -- DEVELOP A DECISION RULE

5.1 PURPOSE

The purpose of DQO Step 5 is to define the parameter of interest (e.g., mean), specify the action level, and integrate outputs from the previous DQO steps into a single statement that describes a logical basis for choosing among alternative actions.

5.2 WORKSHEETS FOR STEP 5 -- DEVELOP A DECISION RULE

The statistical parameter of interest that characterizes the population is defined in Table 5-1.

Table 5-1. Statistical Parameter of Interest that Characterizes the Population. (2 pages)

DS #	Decision Statement Summary	Parameter of Interest
1	Determine if excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3, and UPR-100-N-31) meets ERDF waste acceptance criteria and can be disposed in the ERDF or if alternate disposal options need to be considered.	Direct reading of field survey instruments.
2	Determine if debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meets requirements for disposal in onsite inert/demolition waste landfills or if alternate disposal options need to be considered.	Mean calculated from analytical laboratory results.
3	Determine if soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD and require additional remediation or if remedial action is complete.	<u>Shallow zone, metals</u>: For each metal (Ecology 1995): • The concentration that represents the population maximum • The proportion of the population concentration that exceeds the cleanup level • The true population mean.
		<u>Shallow zone, radionuclides</u>: The dose modeled from radionuclide concentrations representing the 95% UCL on the true population mean.
		<u>Deep zone, metals and radionuclides</u>: The concentration in groundwater modeled from the concentrations representing the true population mean in soil of each COC.

Table 5-1. Statistical Parameter of Interest that Characterizes the Population. (2 pages)

DS #	Decision Statement Summary	Parameter of Interest
4	Determine if contamination levels of overburden and layback soil exceed site criteria identified in the interim remedial action ROD for meet criteria for backfill or if soil must be disposed in the ERDF.	Metals (Ecology 1995): • The concentration that represents the population maximum • The proportion of the population concentration that exceeds the cleanup level • The concentration representing the true population mean. Radionuclides: The dose modeled from radionuclide concentrations representing the 95% UCL on the true population mean.
5	Determine if contamination levels of borrow pit soil meet site criteria for use as backfill or if alternate backfill material must be used.	Maximum.
6	Determine if contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet site criteria identified in the CMS/closure plan for being left in place or if the pipelines must be removed and disposed appropriately (ERDF or inert/demolition waste landfill).	Ecology (1995): • The concentration that represents the population maximum • The proportion of the population concentration that exceeds the cleanup level • The concentration representing the true population mean.

UCL = upper confidence limit

Table 5-2 specifies the scale of decision making.

Table 5-2. Scale of Decision Making.

PSQ #	Scale of Decision Making
1	Volume of excavated soil/debris in one ERDF roll-on/roll-off container.
2	Volume of each waste stratum sent to inert/demolition landfill.
3	Exposed surface of deep zone and/or shallow zone after excavation is complete.
4	Volume of overburden/layback soil stockpiled from each remediation site.
5	Exposed surface of borrow pit soil before the soil is excavated and hauled to the remediation site.
6	Length of feed pipeline.
7	The surface area of the bottom of the 116-N-3 Trench in a transition zone approximately 10-m (30-ft) long.

The action levels or preliminary action levels for each of the decision statements are specified in Table 5-3.

Table 5-3. Action Level for the Decision. (2 pages)

DS #	COPC	Action Level	
	Radionuclides (pCi/g)		
1	Americium-241	25,500	
	Cesium-137	16,300,000	
	Cobalt-60	No limit	
	Europium-154	No limit	
	Europium-155	No limit	
	Nickel-63	3.57E+08	
	Plutonium-239/240	14,000	
	Strontium-90	3.6E+09	
	Tritium	No limit	
	Metals (mg/kg)		
	Chromium (VI)	59,000	
	Mercury	No limit	
	Nitrate	No limit	
	TCLP (mg/L)		
1 and 2	Arsenic	5	
	Barium	100	
	Cadmium	1	
	Chromium (total)	5	
	Lead	5	
	Mercury	0.2	
	Selenium	1	
	Silver	5	
	Inorganics		
	pH (pH units)	<2 or >12.5	
	Radionuclides		
3, 4, and 7	A maximum dose of 15 mrem/yr above background (direct exposure) and 4 mrem/yr[a] (groundwater protection), calculated via RESRAD.		
	Inorganics (mg/kg)		
		Soil [illegible] for Surface Exposure	[illegible] Groundwater/River Protection
	Chromium (VI)	400	2
	Mercury	24	[b]
	Nitrate	113,000	4,400

Table 5-3. Action Level for the Decision. (2 pages)

DS #	COC	Action Level
	Radionuclides	
5	Surveyed per radiation control procedures.	
3 (non-radioactive sites) and 6	*Inorganics (mg/kg)*	
	Antimony	32
	Arsenic	20
	Barium	5,600
	Beryllium	400
	Chromium (III)	80,000
	Chromium (VI)	400
	Copper	2,960
	Lead	353
	Manganese	11,200
	Mercury	24
	Nickel	1,600
	Selenium	400
	Sulfate	25,000[c]
	Thallium	5.6
	Vanadium	560
	Zinc	24,000

[a] The 4 mrem/yr dose is based on target organ protection from the consumption of groundwater as calculated by the NBS Handbook 69 methodology (NBS 1963).
[b] The RESRAD unit gradient model predicts the contaminant will not reach groundwater within 1,000-year time frame.
[c] Based on 100 times the PRG for groundwater/Columbia River protection.

The alternative actions are specified in Table 5-4.

Table 5-4. Alternative Actions. (2 pages)

DS #	AA #	Alternative Action
1	1	Excavated contaminated soil/debris meets ERDF waste acceptance criteria and is disposed in the ERDF.
1	2	Excavated contaminated soil/debris exceeds ERDF waste acceptance criteria and cannot be disposed in the ERDF, and alternative disposal options need to be evaluated.
2	1	Debris meets criteria for disposal in onsite inert/demolition waste landfills and is disposed in onsite inert/demolition landfills.
2	2	Debris exceeds criteria for disposal in onsite inert/demolition waste landfills and is not disposed in onsite inert/demolition landfills.
3	1	Soils meet criteria for protection of groundwater and direct exposure, as specified in the interim remedial action ROD, and remediation efforts are ended.

Table 5-4. Alternative Actions. (2 pages)

DS #	AA #	Alternative Actions
3	2	Soils exceed criteria for protection of groundwater and direct exposure, as specified in the interim remedial action ROD, and remediation efforts are continued.
4	1	Overburden and layback soil meet criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD and are used as backfill.
4	2	Overburden and layback soil exceed criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD and are disposed of as contaminated waste.
5	1	Imported soil from onsite borrow pits meets criteria for use as backfill and is used for backfill.
5	2	Imported soil from onsite borrow pits exceeds criteria for use as backfill and is not used for backfill.
6	1	Pipelines meet the requirements established in the CMS/closure plan for clean sites and are left in place.
6	2	Pipelines exceed the requirements established in the CMS/closure plan for clean sites and are removed.
7	1	Soils meet criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD, and remediation efforts are ended beyond the first dam.
7	2	Soils exceed criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD, remediation efforts are continued in this transition zone, and a new 10-m (30-ft) transition zone is selected for evaluation.

The outputs of DQO Step 5 and the previous DQO steps are combined into "IF...THEN..." decision rules that incorporate the parameter of interest, the scale of decision making, the action level, and the actions that would result from resolution of the decision. The decision rules are listed in Table 5-5.

Table 5-5. Decision Rules. (2 pages)

DR #	Decision Rule
1	If the contaminant concentration of any COC calculated from field surveys exceeds the ERDF waste acceptance criterion for that radionuclide, then the waste cannot be disposed of in the ERDF and alternative disposal options will be investigated.
2	If the true mean contaminant leachate concentration of any COC calculated from laboratory analysis exceeds LDR limits, then the waste cannot be disposed of in an onsite inert/demolition landfill and alternative disposal options will be investigated.

Table 5-5. Decision Rules. (2 pages)

DR #	Decision Rule
3	For soil samples collected from the shallow zone of a remediation site: If the concentration representing the 95% UCL on the true population mean for each inorganic COC does not exceed the MTCA Method B cleanup level for that inorganic, no inorganic COC concentration exceeds twice the MTCA Method B cleanup level, no more than 10% of the inorganic COC concentrations exceed the MTCA Method B cleanup level, total hazard index is less than one, total excess cancer risk is less than one in 100,000, and the dose rate calculated from the 95% UCL on the true population mean for each radionuclide and the total COCs does not exceed 15 mrem/yr above background levels, then the shallow zone of the site will be designated as remedied and site closeout can proceed.
4	For samples of overburden/layback and concrete debris: If the concentration representing the 95% UCL on the true population mean for each inorganic COC does not exceed the MTCA cleanup level for that inorganic, no inorganic COC concentration exceeds twice the MTCA cleanup level, no more than 10% of the inorganic COC concentrations exceed the MTCA cleanup level, total hazard index is less than one, total excess cancer risk is less than one in 100,000, and the dose rate calculated from the 95% UCL on the true population mean for each radionuclide and the total COCs does not exceed 15 mrem/yr above background levels, then the overburden/layback/concrete debris may be used to backfill the shallow zone of the site.
5	For soil samples collected from the deep zone of a remediation site: If the predicted concentration in the groundwater, modeled from concentrations representing the 95% UCL on the true population mean for each inorganic and radionuclide COC is less than the RAO for each COC, then the deep zone of the site will be designated as remedied and site closeout can proceed.
6	For samples of overburden/layback and concrete debris: If the predicted concentration in the groundwater modeled from concentrations representing the 95% UCL on the true population mean for each inorganic and radionuclide COC is less than the RAO for each COC, then the overburden/layback/borrow pit soil and concrete debris may be used to backfill the deep zone of the remediation site.
7	For samples collected from the nonradioactive sites pipelines: If the concentration representing the 95% UCL on the true population mean for each inorganic COC does not exceed the MTCA Method B cleanup level for that inorganic, no inorganic COC concentration exceeds twice the MTCA Method B cleanup level, no more than 10% of the inorganic COC concentrations exceed the MTCA Method B cleanup level, total hazard index is less than one, and total excess cancer risk is less than one in 100,000, then the pipelines will be designated as clean and they do not need to be removed.
8	For soil samples collected from the shallow zone of a 10-m (30-ft) transition zone beyond the first dam: If the concentration representing the 95% UCL on the true population mean for each inorganic COC does not exceed the MTCA Method B cleanup level for that inorganic, no inorganic COC concentration exceeds twice the MTCA Method B cleanup level, no more than 10% of the inorganic COC concentrations exceed the MTCA Method B cleanup level, total hazard index is less than one, total excess cancer risk is less than one in 100,000, and the dose rate calculated from the 95% UCL on the true population mean for each radionuclide and the total COCs does not exceed 15 mrem/yr above background levels, then the shallow zone of the site will be designated as remedied and the remainder of the trench will not be remediated.

6.0 STEP 6 -- SPECIFY TOLERABLE LIMITS ON DECISION ERRORS

6.1 PURPOSE

The purpose of DQO Step 6 is to develop tolerable error limits. The probability of making an erroneous decision will be acceptable if it is within these limits. The error limits established in this step will be used to estimate the number of samples and to establish performance goals for the newly collected data.

One of the primary objectives that must be accomplished in DQO Step 6 is to choose between a statistical or judgmental sample design. Sampling designs may be based on statistics or professional judgment; neither approach is deemed to be absolutely correct. The choice between the two designs depends on the project task objectives, existing data, actions to be taken, and the severity of the consequences of making decision errors.

6.2 WORKSHEETS FOR STEP 6 -- SPECIFY TOLERABLE LIMITS ON DECISION ERROR

Table 6-1 outlines the severity of the consequences of each alternative action developed in DQO Steps 2 and 4.

Table 6-1. DQO Steps 2 and 4 Consequences Severity Summary. (2 pages)

DQO Step	PSQ #	AA #	Consequence Severity	Preliminary DQO Step 6 Sample Design Basis
Step 2	1	1	Moderate	Judgmental
		2	Low	
	2	2	Moderate	Statistical
		2	Low	
	3	1	Severe	Statistical
		2	Low	
	4	1	Severe	Statistical
		2	Low	
	5	1	Low	Judgmental
		2	Low	
	6	1	Moderate	Judgmental
		2	Low	
	7	1	Severe	Statistical
		2	Low	

Table 6-1. DQO Steps 2 and 4 Consequences Severity Summary. (2 pages)

DQO Step	PSQ #	AA #	Consequence Severity	Preliminary DQO Step 6 Sample Design Basis
Step 4	1	---	Not severe	Judgmental
	2	---	Not severe	Statistical
	3	---	Severe	Statistical
	4	---	Severe	Statistical
	5	---	Not severe	Judgmental
	6	---	Not severe	Judgmental
	7	---	Severe	Statistical

Table 6-2 identifies the range of values for the COCs.

Table 6-2. COC Range Values. (2 pages)

WS #	Media	COCs	Range	
			Lower Limit	Upper Limit
		Radionuclides (pCi/g)		
1, 2 and 3	Soil	Americium-241[a]	0	44,700
		Cesium-137[a]	0	429,000
		Cobalt-60[a]	0	2,754,000
		Europium-154[b]	0	170,000
		Europium-155[b]	0	4,120
		Nickel-63	0	---
		Plutonium-239/240[a]	0	52,200
		Strontium-90[a]	0	132,000
		Tritium	0	---
		Inorganics (mg/kg)		
		Chromium (total)[b]	0	57.7
		Chromium (VI)	0	---
		Mercury	0	---
		Nitrate	0	---
		Inorganics (mg/kg)		
		pH (pH units)	---	---

Table 6-2. COC Range Values. (2 pages)

WS	Media	COCs	Range	
			Lower Limit	Upper Limit
		Inorganics (mg/kg)		
4	Soil[b]	Antimony	3.4	12.7
		Arsenic	0.46	2.9
		Barium	41.5	93.7
		Beryllium	16.8	93.7
		Cadmium	0.2	1.48
		Chromium	2.8	14.6
		Copper	5.2	30.6
		Lead	1.5	6.4
		Manganese	73.8	702
		Mercury	0.12	0.27
		Nickel	3.6	15.5
		Selenium	0.42	2.5
		Silver	0.5	2.5
		Thallium	0.29	0.63
		Vanadium	6.6	81.1
		Zinc	13.6	94.4
		pH (pH units)	5.6	9.8
		Sulfate	6	130

[a] Values taken from BHI (1999c).
[b] Values taken from DOE-RL (1998a).

Figure 6-1 provides a flow diagram outlining the preliminary determination of the need for a statistically based or professional judgment-based sample design.

Figure 6-1. Preliminary Determination of the Need for a Statistically Based or Professional Judgment-Based Sample Design.

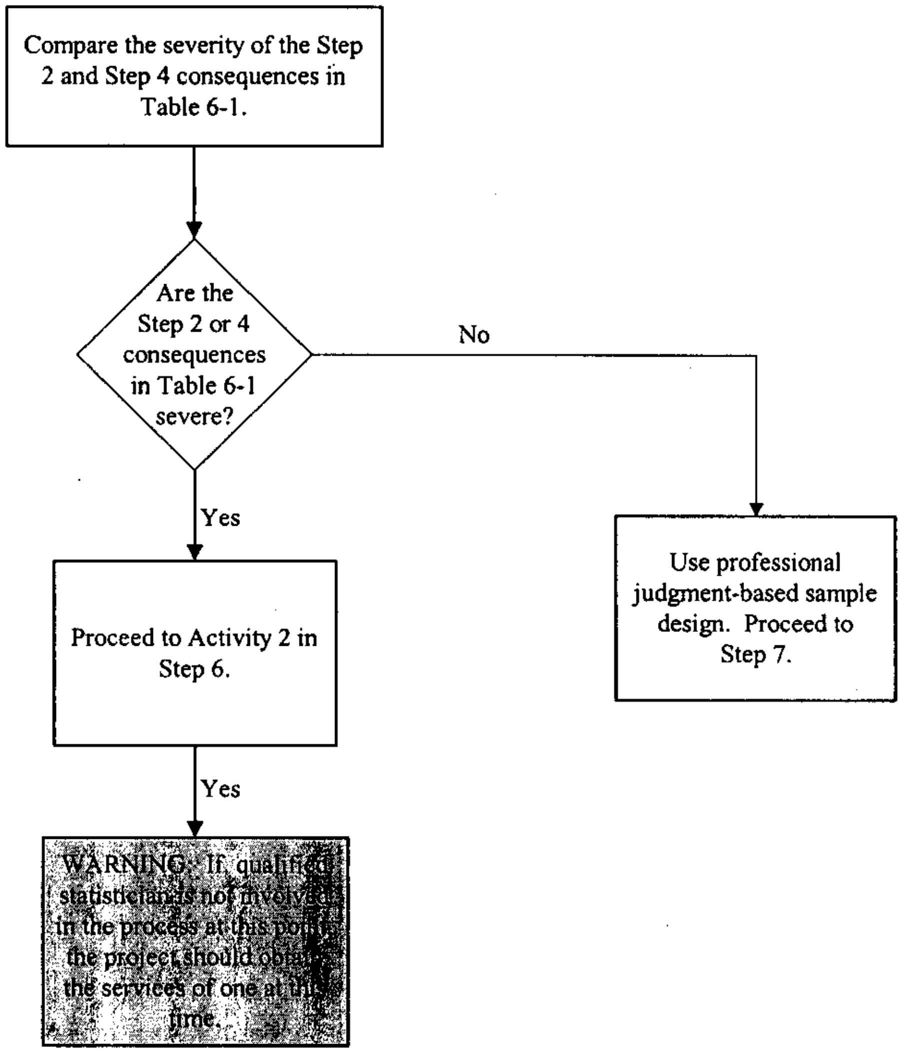


Table 6-3 provides a general statement of the null hypothesis and a specific null hypothesis for each decision statement.

Table 6-3. Statement of the Null Hypothesis (H_o).

The waste sites contain contaminants at concentrations that exceed cleanup levels or disposal waste acceptance criteria.

H_o for DS #1: The excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3, and UPR-100-N-31) exceeds ERDF waste acceptance criteria.

H_o for DS #2: The debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) exceeds requirements for disposal in onsite inert/demolition waste landfills.

H_o for DS #3: The soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan (120-N-1, 120-N-2, and 100-N-58).

H_o for DS #4: The contamination levels of overburden and layback soil exceed the criteria identified in the interim remedial action ROD for use as backfill.

H_o for DS #5: The contamination levels of borrow pit soils exceed criteria for use as backfill.

H_o for DS #6: The contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) exceed site criteria identified in the CMS/closure plan for being left in place.

H_o for DS #7: The soils in the transition zone near the first dam exceed site cleanup criteria identified in the interim remedial action ROD.

The action levels for the COCs identified for each decision statement are listed in Table 6-4.

Table 6-4. Action Level for the Decision. (3 pages)

DS #	COCs	Action Level
	Radionuclides (pCi/g)	
1	Americium-241	25,500
	Cesium-137	16,300,000
	Cobalt-60	No limit
	Europium-154	No limit
	Europium-155	No limit
	Nickel-63	3.57E+08
	Plutonium-239/240	14,000
	Strontium-90	3.6E+09
	Tritium	No limit
	Metals (mg/kg)	
	Chromium (total)	59,000
	Mercury	No limit
	Nitrate	No limit

Table 6-4. Action Level for the Decision. (3 pages)

DS	COC	Action Level		
	TCLP (mg/L)			
	Arsenic	5		
	Barium	100		
	Cadmium	1		
	Chromium (total)	5		
	Lead	5		
	Selenium	1		
	Silver	5		
	Mercury	0.2		
2	*Inorganics*			
	pH (pH units)	<2 or >12.5		
	TCLP (mg/L)			
	Antimony	32		
	Arsenic	5		
	Barium	100		
	Beryllium	400		
	Cadmium	1		
	Chromium (total)	5		
	Copper	2,960		
	Lead	5		
	Manganese	11,200		
	Mercury	0.2		
	Nickel	1,600		
	Selenium	1		
	Silver	5		
	Thallium	6		
	Vanadium	560		
	Zinc	24,000		
3, 4, and 7	*Radionuclides*			
	A maximum dose of 15 mrem/yr above background (direct exposure), and 4 mrem/yr[a] (groundwater protection), calculated using RESRAD.			
	COC	Soils 0 to 15 ft bgs for Surface Exposure	Subsurface Soil >15 ft bgs for Groundwater/River Protection	Action Level (Based on More Restrictive Requirement)
	Inorganics (mg/kg)			
	Chromium (III)	80,000	[b]	80,000
	Chromium (VI)	400	2	2
	Mercury	24	[b]	24
	Nitrate	N/A	4,400	4,400

Table 6-4. Action Level for the Decision. (3 pages)

DSI	COCs	Action Level
	Radionuclides	
5	Surveyed per radiation control procedures.	
3 (non-radiological sites) and 6	COC	Action Level
	Inorganics (mg/kg)	
	Arsenic	20
	Barium	5,600
	Cadmium	80
	Chromium (III)	80,000
	Chromium (VI)	400
	Lead	353
	Mercury	24
	Selenium	400
	Silver	400
	pH (pH units)	<2 or >12.5
	Sulfate	25,000

[a] The 4 mrem/yr dose is based on target organ protection from the consumption of groundwater as calculated by the NBS Handbook 69 methodology (NBS 1963).

[b] The RESRAD unit gradient model predicts the contaminant will not reach groundwater within 1,000-year time frame.

N/A = not applicable

Table 6-5 identifies the decision error statements. Decisions in this project fall into three basic categories: (1) decisions regarding acceptance criteria for disposal (in the ERDF or in an onsite inert/demolition landfill), (2) cleanup decisions (allowing remediation to stop), and (2) decisions regarding whether materials can be used as backfill.

Table 6-5. Decision Error Statements. (2 pages)

Decision Error	Definition
<u>False-positive decision error</u> -- The false-positive decision error occurs when the null hypothesis is rejected when it is true. A statistician refers to a false-positive error as a "Type I error." The measure of the size of the error is called the alpha (α), the level of significance, or the size of the critical region. <u>False-negative decision error</u> -- The false-negative decision error arises when the decision-maker fails to reject the null hypothesis when it is false. A statistician usually refers to a false-negative error as a "Type II error." The measure of the size of the error is called beta (β), and is also known as the complement of the *power* of a hypothesis test.	
Disposal Decisions (DS [illegible])	
False-positive	Incorrectly deciding that contaminated materials do not exceed disposal criteria and incorrectly sending the materials to the ERDF, etc.
False-negative	Incorrectly deciding that contaminated materials do exceed disposal criteria and unnecessarily exploring alternative disposal options.

Table 6-5. Decision Error Statements. (2 pages)

Decision Error	Definition
Cleanup Decisions (DS #3, #6, and #7)	
False-positive	Incorrectly deciding to end remediation efforts.
False-negative	Incorrectly deciding that remediation efforts must continue.
Backfill Decisions (DS #4 and #5)	
False-positive	Incorrectly deciding that contaminated overburden/layback soil and/or concrete debris can be used as backfill.
False-negative	Incorrectly deciding that uncontaminated overburden/layback soil and/or concrete debris must be disposed of as contaminated waste.

The worst-case decision errors are identified in Table 6-6.

Table 6-6. Worst-Case Decision Error Determination.

Decision Error	Severity of Decision Error Near the Action Level
Type I: Incorrectly deciding to end remediation efforts.	Severe
Type II: Incorrectly deciding that remediation efforts must continue.	Moderate
Type I: Incorrectly deciding that contaminated overburden/layback soil can be used as backfill.	Severe
Type II: Incorrectly deciding that uncontaminated overburden/layback soil must be disposed of as contaminated waste.	Moderate
Type I: Incorrectly deciding that contaminated materials do not exceed disposal criteria and incorrectly sending them to the ERDF, etc.	Moderate
Type II: Incorrectly deciding that contaminated materials do exceed disposal criteria and unnecessarily exploring alternative disposal options.	Low

Potential consequences of decision errors are listed in Table 6-7.

Table 6-7. Potential Consequences of Decision Errors.

Type of Decision Error	Impact	Potential Consequences
False-positive: Incorrectly deciding to end remediation efforts.	Human health risks, and political and legal ramifications	Severe
False-negative: Incorrectly deciding that remediation efforts must continue.	Economic costs	Moderate
False-positive: Incorrectly deciding that contaminated overburden/ layback soil and/or concrete debris can be used as backfill.	Human health and ecological risks, and political and legal ramifications	Severe
False-negative: Incorrectly deciding that uncontaminated overburden/ layback soil and/or concrete debris must be disposed of as contaminated waste.	Economic costs	Moderate
Incorrectly deciding that contaminated materials do not exceed disposal criteria and incorrectly sending the materials to the ERDF, etc.	Human health risks, and political and legal ramifications	Moderate
Incorrectly deciding that contaminated materials do exceed disposal criteria and unnecessarily exploring alternative disposal options.	Human health and ecological risks, and political and legal ramifications	Low

Figure 6-2 provides a flowchart on the determination of the need for a statistically based or professional judgment-based sample design.

Figure 6-2. Determination of the Need for a Statistically Based or Professional Judgment-Based Sample Design.

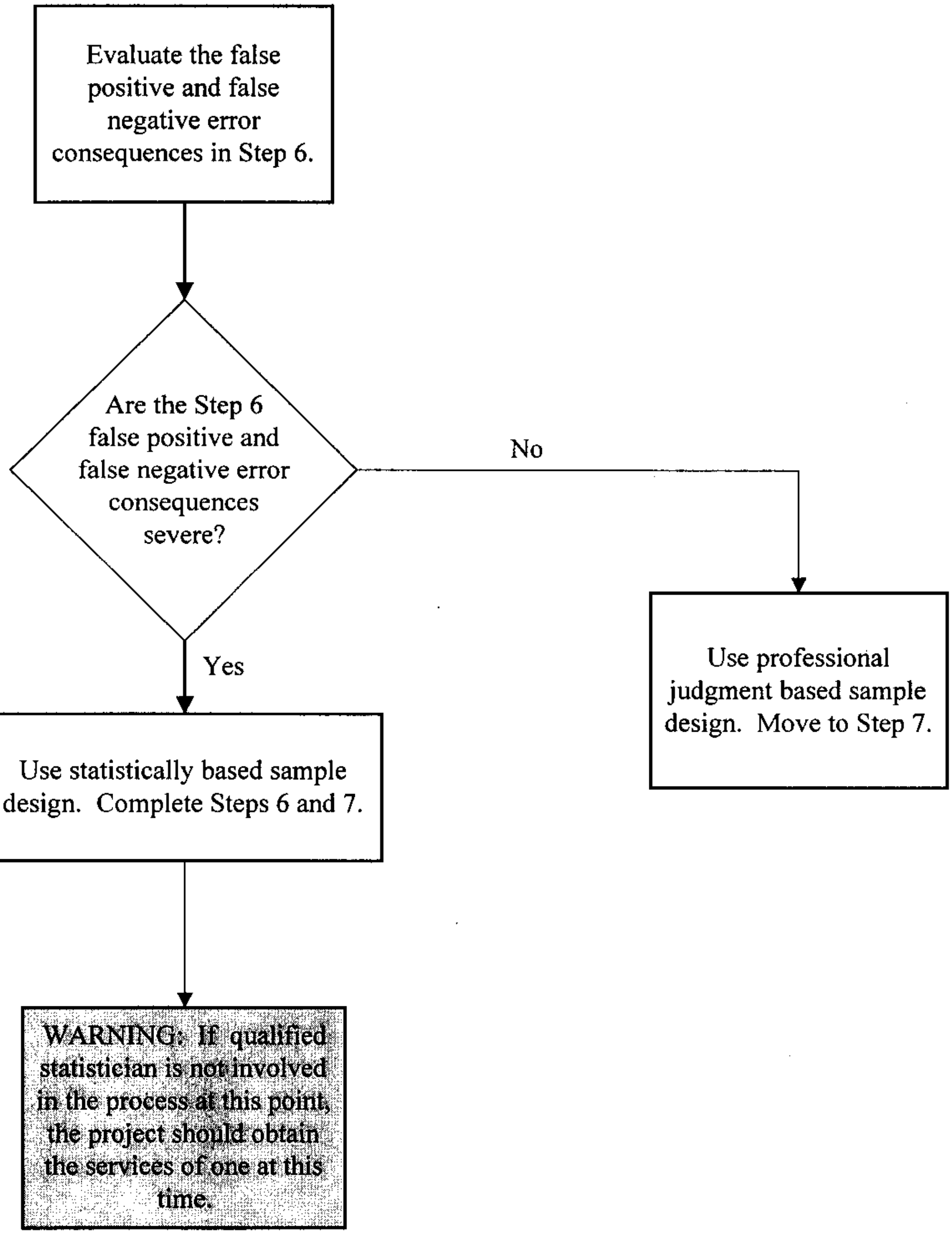


Table 6-8 provides a definition of the gray region, which applies to all decision statements.

Table 6-8. Gray Region Definition.

Between the action level and 80% of the action level for each COC.

For each COC and each statistical test of interest, tolerable levels of decision error (the largest decision error factors that can tolerated and still resolve the decision statements) are provided for the positive and negative zones and the gray region. Table 6-9 contains the tolerable decision errors.

For all cleanup and disposal decisions (DS #3 through #7), the following apply:

- The statistical test of interest is a one-tailed 95% upper confidence limit (UCL)
- The false-positive (α) error rate is 5%
- The false-negative (β) error rate is 20%
- The lower bound of the gray region is 80% of the corresponding action level.

Table 6-9. Tolerable Decision Errors. (2 pages)

DS #	Media	COC	Test Statistic of Interest	Range		Tolerable Decision Error	
						False Positives (%)	False Negatives (%)
		Inorganics					
2	Debris that contacted liquid effluents from the 120-N-1, 120-N-2, and 100-N-58 percolation pond system	pH (pH units)	Sample mean	2	12.5	5	20
		TCLP (mg/L)					
		Arsenic	Sample mean	0	5	5	20
		Barium		0	100	5	20
		Cadmium		0	1	5	20
		Chromium (total)		0	5	5	20
		Lead		0	5	5	20
		Mercury		0	0.2	5	20
		Selenium		0	1	5	20
		Silver		0	5	5	20
		Radioisotopes (pCi/g)					
3, 4, and 7	Remaining soil; and/or overburden/ layback soil for use as backfill in the shallow zone, radiological sites	Americium-241	95% UCL estimate of the true population mean, calculated from the sampling data	0	41.6	5	20
		Cesium-137		0	6.1	5	20
		Cobalt-60		0	1.4	5	20
		Europium-154		0	3.1	5	20
		Europium-155		0	127	5	20
		Nickel-63		0	4,031	5	20
		Plutonium-239/240		0	23.5	5	20
		Strontium-90		0	3.7	5	20
		Tritium		0	241	5	20

Table 6-9. Tolerable Decision Errors. (2 pages)

DS #	Media	COCs	Test Statistic of Interest	Range[a]		Tolerable Decision Error	
						False Positives (%)	False Negatives (%)
		Inorganics (mg/kg)					
		Chromium (VI)	95% UCL estimate of the true population mean, calculated from the sampling data	0	400	5	20
		Mercury		0	24	5	20
		Nitrate		0	4,400	5	20
		Inorganics (mg/kg)					
3 and 6	Soil and pipe scale from the 120-N-1, 120-N-2, and 100-N-58 percolation system	Antimony	95% UCL estimate of the true population mean, calculated from the sampling data	0	32	5	20
		Arsenic		0	20[c]	5	20
		Barium		0	5,600	5	20
		Beryllium		0	400	5	20
		Cadmium		0	80	5	20
		Chromium (III)		0	80,000	5	20
		Chromium (VI)		0	400	5	20
		Copper		0	2,960	5	20
		Lead		0	353	5	20
		Manganese		0	11,200	5	20
		Mercury		0	24	5	20
		Nickel		0	1,600	5	20
		Nitrate		0	4,400	5	20
		Selenium		0	400	5	20
		Silver		0	400	5	20
		Thallium		0	6	5	20
		Sulfate		0	25,00	5	20
		Vanadium		0	560	5	20
		Zinc		0	24,000	5	20
		pH (pH units)		2	12.5	5	20

[a] Upper end of range taken to be the concentration representing 15 mrem/yr limit for each radionuclide alone or the cleanup standard for nonradionuclides.

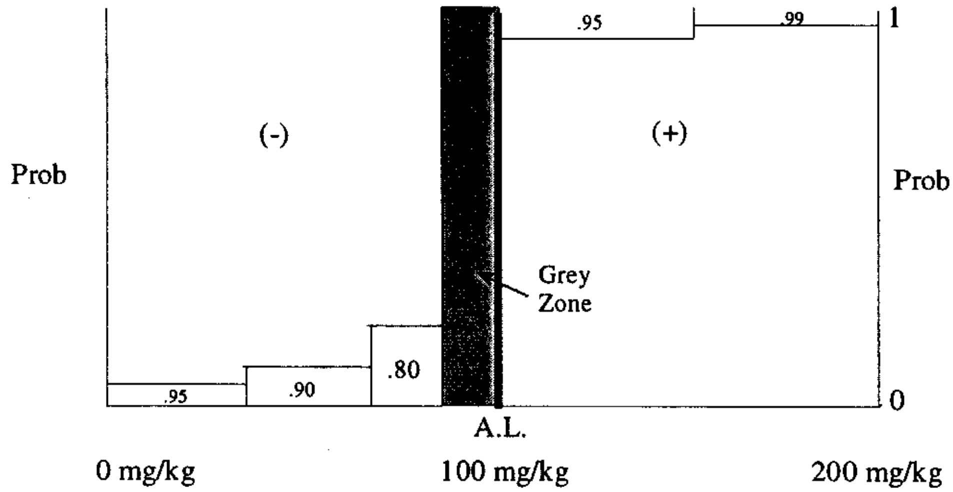
The boundaries of the gray region are shown in Table 6-10.

Table 6-10. Boundaries of the Gray Region.

Media	COCs	Gray Region Boundaries
All	All	80% of action level to 100% of action level

Figure 6-3 provides a graph of the true value of the parameter.

Figure 6-3. Graph of True Value of the Parameter.



7.0 STEP 7 – OPTIMIZE THE DESIGN

7.1 PURPOSE

The purpose of DQO Step 7 is to identify the most resource-effective design while not exceeding the tolerable false-positive and false-negative decision error rates (which were specified in DQO Step 6 for generating data to support decisions), while maintaining the desired degree of precision and accuracy. Table 7-1 identifies the data collection design determination.

Table 7-1. Data Collection Design Determination. (2 pages)

Decision	Statistical	Non-statistical	Rationale
1. Determine if excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3, and UPR-100-N-31) meets ERDF waste acceptance criteria and can be disposed in the ERDF or if alternate disposal options need to be considered.		X	Process knowledge and sampling data indicate that waste materials will not exceed ERDF waste acceptance criteria. Judgmental samples will be used to confirm the waste profile. **Note:** This data collection design is really a quasi-statistical design. Samples will be taken systematically (as opposed to judgmentally), because every excavator bucket will be screened for gamma activity to ensure that safety requirements are met. If a given bucket exceeds the safety limits, then the contents will be returned to the trench or crib, remixed with other materials, and re-screened until the contents of the bucket pass the safety requirements. Because every bucket is below the safety requirement, the average of the buckets will also be below the safety limit. Although the 95% UCL will not be formally calculated, it is reasonable to assume that since a large number of buckets will be screened, the 95% UCL will be very close to the mean, which will be below the safety limits. Using the measured gamma activity as the basis, the percent of profile for ERDF waste acceptance COCs will be estimated.
2. Determine if debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meets requirements for disposal in onsite inert/demolition waste landfills or if alternate disposal options need to be considered.	X		Process knowledge and sampling data indicate that waste debris materials will not exceed the levels for disposal in onsite inert/demolition landfills.
3. Determine if soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan and require additional remediation or if remedial action is complete.	X		The MTCA rules for site closeout require a statistically based sample design.

Table 7-1. Data Collection Design Determination. (2 pages)

Decision	Statistical	Non-Statistical	Rationale
4. Determine if contamination levels of overburden and layback soil exceed site criteria identified in the interim remedial action ROD meet criteria for backfill or if the soil must be disposed in the ERDF.	X		The MTCA rules for site closeout require a statistically based sample design.
5. Determine if contamination levels of borrow pit soil meet site criteria identified in the interim remedial action ROD for use as backfill or if alternate backfill material must be used.		X	Process knowledge/history indicates that borrow pits have never been exposed to radioactive or chemical contaminants.
6. Determine if contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet site criteria identified in the CMS/closure plan for being left in place or if the pipelines must be removed and disposed appropriately (ERDF or inert/demolition waste landfill).		X	The MTCA rules for site closeout require a statistically based sample design. However, access constraints on the pipeline make a statistically based design very difficult and expensive to implement. Process history and sampling results from the settling ponds indicate that the sites are clean, so by inference, the pipelines have a high probability of being clean.
7. Determine if soils in the transition zone near the first dam of the 116-N-3 Trench exceed site cleanup criteria identified in the CMS/closure plan and additional remediation is needed or if remedial action is complete up to this transition zone.	X		The transition zone must meet the same closeout requirements as the remediated portion of the 116-N-3 Trench (see decision #3). The MTCA rules for site closeout require a statistically based sample design.

The data collection design alternatives are identified in Table 7-2.

Table 7-2. Data Collection Design Alternatives.

Decision	Haphazard	Judgmental
1. Determine if excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3, and UPR-100-N-31) meets ERDF waste acceptance criteria and can be disposed in the ERDF or if alternate disposal options need to be considered.		X
5. Determine if contamination levels of borrow pit soil meet site criteria identified in the interim remedial action ROD for use as backfill or if alternate backfill material must be used.		X
6. Determine if contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet site criteria identified in the CMS/closure plan for being left in place or if the pipelines must be removed and disposed appropriately (ERDF or inert/demolition waste landfill).		X

If the data collection design for a given decision will be statistical, determine what type of statistical design is appropriate. State the null hypothesis that will be tested after the data are collected. The null hypothesis includes the statistical characteristic of interest, the action level, and the relationship between them.

The types of statistical designs generally used in environmental problems include the following:

- Simple random
- Stratified random
- Sequential
- Systematic
- Geostatistical
- Factorial.

Table 7-3 identifies the statistical design determination.

Table 7-3. Statistical Design Determination. (2 pages)

Decision	Type of Statistical Design	Null Hypothesis of Interest
2. Determine if debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meets requirements for disposal in onsite inert/demolition waste landfills or if alternate disposal options need to be considered.	Random sampling	H_0 for DS #2: The debris exceeds criteria for disposal in inert/demolition waste landfills.
3. Determine if soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan and require additional remediation or if remedial action is complete.	Random sampling	H_0 for DS #3: The soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan.

Table 7-3. Statistical Design Determination. (2 pages)

Decision	Type of Statistical Design	Null Hypothesis of Interest
4. Determine if contamination levels of overburden and layback soil exceed site criteria identified in the interim remedial action ROD for meet criteria for if backfill or must be disposed in ERDF.	Random sampling	H_0 for DS #4: The contaminated levels of overburden and layback soil exceed the criteria identified in the interim remedial action ROD for use as backfill.
7. Determine if soils in the transition zone near the first dam of the 116-N-3 Trench exceed site cleanup criteria identified in the interim remedial action ROD and additional remediation is needed, or determine if remedial action is complete up to this transition zone.	Random sampling	H_0 for DS #7: The soils in the transition zone exceed site cleanup criteria identified in the interim remedial action ROD.

Table 7-4 and 7-4a further describe the strategy for each decision statement.

Table 7-4. Sampling Strategies. (6 pages)

DS #	Decision Statement	WS #	Geographical Area of Interest	Strata	Rationale	Data and Decision Type	Sampling Measurement Design (See Table 7-3b)	Number of Measurements To Be Taken
1	Determine if excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3 and UPR-100-N-31) meets ERDF waste acceptance criteria and can be disposed in the ERDF or if alternate disposal options need to be considered.	1	116-N-1 Crib and associated pipelines	Layer of contaminated boulders and cobbles	Boulders and cobbles have much lower surface area to volume ratio than underlying soils. If underlying soils meet ERDF waste acceptance criteria, boulders and cobbles will also meet the waste acceptance criteria. Excavated materials will be screened on bucket-by-bucket basis for health and safety. This screening, correlated with analytical laboratory results, is sufficient to satisfy ERDF waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
				Contaminated native soil	Excavated materials will be screened on bucket-by-bucket basis for health and safety. This screening, correlated with analytical laboratory results, is sufficient to satisfy ERDF waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
				Contaminated pipelines/ debris	Pipelines and debris have much lower surface area to volume ratio than underlying soils. If underlying soils meet ERDF waste acceptance criteria, pipes and debris will also meet the waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer

Table 7-4. Sampling Strategies. (6 pages)

DS #	Decision Statement	WS #	Geographical Area of Interest	Strata	Rationale	Data and Decision Type	Sampling, Measurement Design (See Table 7-3b)	Number of Measurements To Be Taken
			UPR-100-N-31	Contaminated native soil	Excavated materials will be screened on bucket-by-bucket basis for health and safety. This screening, correlated with analytical laboratory results is sufficient to satisfy ERDF waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
		2	116-N-1 Trench and cover panels	Cover panels/telephone poles (rubblized)	Cover panels have much lower surface area to volume ratio than underlying soils. If underlying soils meet ERDF waste acceptance criteria, cover panels will also meet the waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
				Contaminated native soil	Excavated materials will be screened on bucket-by-bucket basis for health and safety. This screening, correlated with analytical laboratory results, is sufficient to satisfy ERDF waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
		3	116-N-3 Crib and Trench, cover panels, and associated pipelines	Cover panels (rubblized)	Cover panels have much lower surface area to volume ratio than underlying soils. If underlying soils meet ERDF waste acceptance criteria, cover panels will also meet the waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
				Cover panels (removed intact)	Cover panels have much lower surface area to volume ratio than underlying soils. If underlying soils meet ERDF waste acceptance criteria, cover panels will also meet the waste acceptance criteria.	Field screening data with judgmental decision	Design B: 116-N-3 Crib cover panels	Approx. 10% of removed sections with a minimum of 30 surveys

Table 7-4. Sampling Strategies. (6 pages)

DS #	Decision Statement	WS #	Geographical Area of Interest	Strata	Rationale	Data and Decision Type	Sampling, Measurement Design (See Table 7-3b)	Number of Measurements To Be Taken
				Contaminated native soil	Excavated materials will be screened on bucket-by-bucket basis for health and safety. This screening, correlated with analytical laboratory results, is sufficient to satisfy ERDF waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
				Contaminated pipelines/ debris	Pipelines and debris have much lower surface area to volume ratio than underlying soils. If underlying soils meet ERDF waste acceptance criteria, pipelines and debris will also meet the waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
				Grouted main trough	Trough has much lower surface area to volume ratio than underlying soils. If underlying soils meet ERDF waste acceptance criteria, trough will also meet the waste acceptance criteria.	Field screening data with judgmental decision	Design C: grouted main trough, 116-N-3 Crib	Surveyed per radiological control requirements
2	Determine if debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meets requirements for disposal in onsite inert/demolition waste landfills or if alternate disposal options need to be considered.	4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	Liner	Dangerous waste determination based on analytical laboratory results of samples.	Random sampling and statistical decision	Design D: 120-N-1, 120-N-2, and 100-N-58 debris waste designation	Two samples for TCLP analysis
				Pipelines (if they need to be removed)	Dangerous waste determination based on analytical laboratory results of samples.	Random sampling and statistical decision	Design D: 120-N-1, 120-N-2, and 100-N-58 debris waste designation	Two samples for TCLP analysis
				Debris	Dangerous waste determination based on analytical laboratory results of samples.	Random sampling and statistical decision	Design D: 120-N-1, 120-N-2, and 100-N-58 debris waste designation	Two samples for TCLP analysis of each debris type that would have contacted the wastewater (e.g., the sample shed structure [walls, structural steel, roof, etc.] and fencing need not be sampled because they did not contact the wastewater)

Table 7-4. Sampling Strategies. (6 pages)

DS #	Decision Statement	WS #	Geographical Area of Interest	Strata	Rationale	Data and Decision Type	Sampling, Measurement Design (See Table 7-3b)	Number of Measurements To Be Taken
3	Determine if soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD and require additional remediation or if remedial action is complete.	1	116-N-1 Crib and associated pipelines	Surface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure threat.	Random sampling and statistical decision	Design E1: 116-N-1 surface soil closeout	To be calculated, with a minimum of 10 samples
				Subsurface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Random sampling and statistical decision	Design E2: 116-N-1 subsurface soils and overburden/layback	To be calculated, with a minimum of 10 samples
			UPR-100-N-31	Surface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure threat.	Random sampling and statistical decision	Design E1: 116-N-1 surface soil closeout	To be calculated, with a minimum of 10 samples
				Subsurface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Random sampling and statistical decision	Design E2: 116-N-1 subsurface soils and overburden/layback	To be calculated based on variance to be used at 116-N-1 with a minimum of 10 samples
		2	116-N-1 Trench and cover panels	Surface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure threat.	Random sampling and statistical decision	Design E1: 116-N-1 surface soil closeout	To be calculated, with a minimum of 10 samples
				Subsurface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Random sampling and statistical decision	Design E2: 116-N-1 subsurface soils and overburden/layback	To be calculated, with a minimum of 10 samples

Table 7-4. Sampling Strategies. (6 pages)

DS #	Decision Statement	WS #	Geographical Area of Interest	Strata	Rationale	Data and Decision Type	Sampling/Measurement Design (See Table 7-3b)	Number of Measurements To Be Taken
		3	116-N-3 Crib and Trench, cover panels, and associated pipelines (upstream of the first dam)	Surface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure threat.	Random sampling and statistical decision	Design E3: 116-N-3 surface soils	To be calculated, with a minimum of 10 samples
				Subsurface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Random sampling and statistical decision	Design E4: 116-N-3 subsurface soils and overburden/layback	To be calculated, with a minimum of 10 samples
		4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	Soil remaining at nonradioactive contaminated sites	Analytical laboratory results, comparison of data to MTCA Method B criteria determine if remediated site presents a threat.	Random sampling and statistical decision	Design F: 120-N-1, 120-N-2, and 100-N-58 site closeout	Two samples in the northeastern portion of the units
4	Determine if contamination levels of overburden and layback soil exceed site criteria identified in the interim remedial action ROD meet criteria for backfill or if the soil must be disposed in the ERDF.	1	116-N-1 Crib and associated pipelines	Overburden/ layback soils	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Random sampling and statistical decision	Design E2: 116-N-1 subsurface soils and overburden/layback	To be calculated, with a minimum of 10 samples
			UPR-100-N-31	Overburden/ layback soils	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Random sampling and statistical decision	Design E1: 116-N-1 surface soil closeout.	To be calculated, with a minimum of 10 samples
		2	116-N-1 Trench and cover panels	Overburden/ layback soils	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Random sampling and statistical decision	Design E2: 116-N-1 subsurface soils and overburden/layback	To be calculated, with a minimum of 10 samples
		3	116-N-3 Crib and Trench (upstream of the first dam), associated cover panels, and associated pipelines	Overburden/ layback soils	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Systematic sampling and statistical decision	Design E4: 116-N-3 subsurface soils and overburden/layback	Ten or more, as required by process

Table 7-4. Sampling Strategies. (6 pages)

DS #	Decision Statement	WS #	Geographical Area of Interest	Strata	Rationale	Data and Decision Type	Sampling, Measurement Design (See Table 7-3b)	Number of Measurements To Be Taken
5	Determine if contamination levels of borrow pit soil meet site criteria for use as backfill or if alternate backfill material must be used.	1, 2, 3, and 4	116-N-1, 116-N-3, UPR-100-N-31, 120-N-1, 120-N-2, 100-N-58 Crib, and associated pipelines	Borrow pit soil	Process knowledge and field screening.	Field screening with judgmental decision	Based on radiation control practices and procedures	A minimum of 10 % of the surface area of the borrow pit
6	Determine if contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet site criteria identified in CMS/closure plan for being left in place or if the pipelines must be removed and disposed appropriately (ERDF or inert/demolition waste landfill).	4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	Pipelines	Comparison of analytical laboratory results with MTCA Method B limits from samples taken from the interior of the pipelines. Pipelines have very limited access.	Convenience sampling with judgmental decision	Design G: 120-N-1, 120-N-2, and 100-N-58 pipelines	Two samples, one from each end of the pipeline
7	Determine if soils in the transition zone near the first dam of the 116-N-3 Trench exceed site cleanup criteria identified in the interim remedial action ROD and additional remediation is needed or determine if remedial action is complete up to this transition zone.	3	116-N-3 Trench (downstream of the first dam) and associated cover panels	Subsurface soil remaining after caving in cover panels	Rather than surveying and sampling the entire length of the trench downstream of the first dam, a clean transition zone will be identified downstream of the first dam. It is reasonable to assume that if a clean transition zone can be identified and characterized, then all soils downstream of that transition zone will be clean as well.	Systematic sampling and statistical decision	Design H: transition zone downstream of first dam, 116-N-3 Trench	Twelve or more, as required by the process

Table 7-4a. Sampling Designs. (3 pages)

Design A: Boulders, cobbles, small debris, contaminated soil, and rubblized cover panels This design refers to materials small enough to fit into ERDF roll-on/roll-off containers. As excavation of the crib and trench proceeds, the contents of each excavator bucket (or section of debris, if too large to fit within an excavator bucket, but otherwise small enough to be placed in an ERDF roll-on/roll-off container) will be surveyed for gamma activity. The relationship between gamma activity and other isotopes of interest (primarily alpha emitters) will be used to ensure that ERDF safety requirements are met. If the gamma level and corresponding isotopic levels exceed safety limits, the bucket contents will be returned to the trench or crib. The percent of profile in the container will be calculated for each COC based on the same correlation of isotopes to the measured gamma activity.
Design B: 116-N- 3 Crib cover panels The 116-N-3 Crib cover panels may be removed intact and placed on a truck for transport to the ERDF. Historical process information indicates that the entire crib was flooded and it is, therefore, reasonable to assume that contamination of the crib covers will be relatively uniform. Initially each panel will be surveyed for removable and non-removable contamination. With experience, depending on the levels of contamination observed, the requirement for survey of every panel will be reduced. The percent of profile in the container will be calculated for each COC based on a correlation to the measured gamma activity.
Design C: Grouted main trough, 116-N-3 Crib The main trough of the 116-N-3 Crib will be filled with grout and then cut into large pieces, approximately 9.2-m (30-ft) long. Each of the trough sections will be surveyed per radiological control requirements.
Design D: 120-N-1, 120-N-2, and 100-N-58 debris waste designation Debris from the 120-N-1, 120-N-2, and 100-N-58 sites will be randomly sampled for dangerous waste determination. Data from previous sampling in the 120-N-1, 120-N-2, and 100-N-58 system (Appendix B of DOE-RL [1998a]) were determined to follow a lognormal distribution (Section B4.3.2 of DOE-RL [1998a]). Because the data are lognormally distributed and because the percentage of nondetects is between 15% and 50%, Cohen's adjustment (as described in Ecology [1993]) was used to obtain a more accurate estimate of the standard deviation of the data. Chromium was the analyte with a mean closest to the action level, and chromium was selected for this analysis (chromium had 32% nondetects). Cohen's adjusted variance (also in natural log units) is 0.251. Using Cohen's adjusted variance, the number of samples needed to have 95% confidence that the estimate of the median contained no more than 20%, 30%, or 100% relative error was calculated. For 100% relative error in the estimate of the median, two samples are needed to have 95% confidence that the sample median (i.e., the estimate of the population median) contains no more than 100% relative error. The 100% relative error was chosen because the maximum values of the data are significantly less than the regulatory limit (as specified in 40 CFR 261.24).

Table 7-4a. Sampling Designs. (3 pages)

Design E1: 116-N-1 surface soil closeout

Because the 116-N-1 Crib and Trench sites are analogous to the 116-N-3 Crib and Trench sites, the number of closeout surface soil samples calculated for the 116-N-3 site will also be used for the 116-N-1 site.

Design E2: 116-N-1 subsurface closeout

Because the 116-N-1 Crib and Trench sites are analogous to the 116-N-3 Crib and Trench sites, the number of closeout subsurface soil samples calculated for the 116-N-3 site will also be used for the 116-N-1 site.

Design E3: 116-N-3 surface soil closeout and overburden/layback soils

After contaminated soil and debris have been removed to a depth of 1.5 m (5 ft) below the bottom of the engineered structure, 30 sampling locations will be randomly selected on the bottom of the trench or crib. These 30 locations will be screened for gamma activity. Using this information, the population variances of the COCs will be estimated. From these, the largest variance estimate will be chosen and used to calculate the number of closeout samples needed. If the data are normally distributed and are not correlated, the t-test would be used to test the hypothesis and the following equation (EPA 1994b) may be used to calculate the minimum number of verification/closeout samples:

$$n_d = \sigma^2 \left\{ \frac{z_{1-\beta} + z_{1-\alpha}}{C_s - \mu_1} \right\}^2 + \frac{1}{2}(z_{1-\alpha})^2$$

where:

	σ	=	the standard deviation.
	$Z_{1-\alpha}$ and $Z_{1-\beta}$	=	the critical values for the normal distribution with probabilities of $1-\alpha$ and $1-\beta$, respectively (.95 and .80 for this calculation).
	C_s	=	the cleanup standard, which will be the limit in Table 5-3.
	μ_1	=	the true mean concentration (less than the cleanup standard value) where the probability is no greater than 0.20 of deciding the site does not meet the cleanup standard. In other words, μ_1 is the lower bound of the "gray region."

If the calculated number of samples is less than 10, then 10 samples will be collected.[a] If the calculated number of samples is greater or equal to 10, then the calculated number of samples will be collected. The locations for the closeout samples will be randomly determined by a process completely separate from the process used for choosing the locations of the variance samples. After collection and analysis, the 95% UCL limits of the COCs will be compared to the appropriate RAGs for surface soils. The RESRAD model will be used to calculate the mrem/yr dose above background, which will be compared to the limit of 15 mrem/yr above background. Chemical contaminant data will be evaluated per MTCA Method B criteria for the following: the concentration representing the 95% UCL on the true population mean for each inorganic COC does not exceed the MTCA Method B cleanup level for that inorganic, no inorganic COC concentration exceeds twice the MTCA Method B cleanup level, no more than 10% of the inorganic COC concentrations exceed MTCA Method B cleanup level, total hazard index is less than one total excess cancer risk is less than one in 100,000, and the dose rate calculated from the 95% UCL on the true population mean for each radionuclide and the total COCs does not exceed 15 mrem/yr above background levels, then the shallow zone of the site will be designated as remedied and site closeout can proceed.

Table 7-4a. Sampling Designs. (3 pages)

Design E4: 116-N-3 subsurface closeout soils Because it is reasonable to assume that the COCs in the subsurface soils will be no more variable than the COCs in the surface soil, the same number of closeout samples will be collected for subsurface closeout and backfill as for surface soil closeout. Samples will be collected from randomly determined locations and the same statistical analyses will be performed. The primary difference is that subsurface decisions have different closeout criteria.
Design F: 120-N-1, 120-N-2, and 100-N-58 site closeout As specified in Section B4.3.3 of the closure plan (Appendix B of DOE-RL [1998a]), two samples will be collected from the northern part of the units. As agreed to at a global issues meeting with the regulators (BHI 1999a), the Washington State Department of Ecology (Ecology) requested that the soil samples be collected from the spill area in the northeast corner of the site at a location and depth to be determined (with the concurrence of Ecology) based on a review of the existing data. This determination will be made considering site conditions after the pond liner has been removed. The new data, combined with the sampling data from the 1992/1993 sampling (Section B4.3.1 of the closure plan [DOE-RL 1998a]), will be sufficient to determine if remediation is complete and if closeout of the site is appropriate.
Design G: 120-N-1, 120-N-2, and 100-N-58 pipeline Because the pipeline is located 12.2 m (40 ft) underground, only two ends of the pipeline are accessible. Random sampling is not a feasible alternative, so samples will be taken from each end of the pipeline. It is reasonable to expect that contamination in the pipeline is fairly uniformly distributed throughout the pipeline. The 95% UCL on the mean of these two samples will be compared to the RAG for each contaminant. If the 95% UCL is below the RAG, then the pipeline will be left in place. If the 95% UCL is above the RAG, then the pipeline will be removed and disposed in an appropriate disposal facility.
Design H: Transition zone downstream of first dam, 116-N-3 Trench To find the transition from the contaminated to the uncontaminated section of the 116-N-3 Trench, the following steps will be taken. The first three cover panels behind the first dam will be caved in and a total of 12 soil samples[b] will be systematically taken, with four samples taken from the center of the trench below each of the three panels. The 95% UCL will be calculated for the 12 samples for all COCs. The RESRAD model will be used to calculate the mrem/yr dose above background. If the dose is below 15 mrem/yr above background, then this and the remaining sections of the trench will be declared clean and no further sampling and analysis of the trench will be required. However, if the dose is greater than 15 mrem/yr above background, then this section will be treated as contaminated. The next three cover panels will be caved in and 12 additional samples will be taken in the same manner. This process will be repeated until a section spanned by three cover panels meets the closeout criteria.

[a] After the closeout/verification samples are collected and analyzed, the assumptions of the statistical test (in this case, the t-test) must be tested to determine if the test is appropriate for the data collected. If the test is not appropriate (e.g., underlying assumptions about the statistical test are not true because the data are not normally distributed, or the data are correlated), a different statistical test may be selected (e.g., a non-parametric test, such as Wilcoxon test). In this case, the number of samples calculated by the equation may not be adequate for the alternative statistical test because it is based on the t-test. The 10-sample minimum is based on a judgment that it is the smallest sample number that would allow alternative testing of the hypothesis. However, there is no guarantee that 10 samples will be adequate, and additional samples may need to be collected.

[b] Lacking pilot study data to calculate the population variance and, from it, the number of verification samples, 12 samples were determined to be a reasonable number that should allow testing of the hypothesis.

The mathematical formula expressions needed to solve the design problems are identified in Table 7-5.

Table 7-5. Mathematical Formula Expressions Needed to Solve Design Problems. (2 pages)

Decision	Null Hypothesis	Method for Testing the Hypothesis	Formula for Number of Samples
2. Determine if debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meets requirements for disposal in onsite inert/demolition waste landfills or if alternate disposal options need to be considered.	The debris exceeds criteria for disposal in inert/demolition waste landfills.	Each debris type from the 120-N-1, 120-N-2, and 100-N-58 sites will be randomly sampled at two locations for dangerous waste determination.	Data are lognormally distributed. Cohen's adjustment (as described by Ecology [1993]) used to obtain an estimate of the standard deviation of previously collected data (Appendix B of DOE-RL [1998a]).
3. Determine if data are within PRGs and support site closeout.	The waste sites contain contaminants at concentrations that exceed cleanup levels.	Shallow zone soils: 95% UCL on the true population mean, calculated from the sampling data. Deep zone soils: 95% UCL on the true population mean, calculated from the sampling data.	$n_d = \sigma^2 \left\{ \frac{z_{1-\beta} + z_{1-\alpha}}{C_s - \mu_1} \right\}^2 + \frac{1}{2}(z_{1-\alpha})^2$ (see note a)
4. Determine if overburden/ layback soil contamination levels are above PRGs and support use as backfill.	The overburden/layback soil contains contaminants at concentrations that exceed cleanup levels.	Overburden/layback soil for shallow zone backfill: 95% UCL on the true population mean, calculated from the sampling data. Overburden/layback soil for deep zone backfill: 95% UCL on the true population mean, calculated from the sampling data.	

Table 7-5. Mathematical Formula Expressions Needed to Solve Design Problems. (2 pages)

Decision	Null Hypothesis	Method for Testing the Hypothesis	Formula for Number of Samples
7. Determine if contamination levels in the soil in the transition zone near the first dam are below PRGs and support cessation of remedial action beyond this transition zone.	The soil contains contaminants at concentrations that exceed cleanup levels.	95% UCL on the true population mean, calculated from the sampling data.	

[a] Equation taken from *Guidance for the Data Quality Objectives Process*, EPA QA/G-4 (EPA 1994b), where:

σ = the standard deviation; if no data are available, value can be estimated by dividing the range by 6 (EPA 1989). The data must be normally distributed to use this estimate.

$Z_{1-\alpha}$ and $Z_{1-\beta}$ = the critical values for the normal distribution with probabilities of $1-\alpha$ and $1-\beta$, respectively (.95 and .80 for this calculation).

C_s = the cleanup standard, which will be the limit in Table 5-3.

μ_1 = the true mean concentration (less than the cleanup standard value) where the probability is no greater than 0.20 of deciding the site does not meet the cleanup standard. In other words, μ_1 is the lower bound of the "gray region."

The use of this equation requires that (1) the data are normally distributed, (2) the data are statistically independent (not correlated), (3) that a valid estimate of the variance of the data (σ^2) is available to use in the formula, and (4) the data are obtained by a probability-based sampling design.

Often the model will describe the components of error or bias that are believed to exist in the measured values. For example, if a mean concentration of a COPC will be measured by a field screening instrument rather than through laboratory analyses, the model that relates the field screening results to the concentration results must be specified, along with any assumptions upon which the model is based. The relationships and assumptions between true and measured values are identified in Table 7-6.

Table 7-6. Relationships and Assumptions Between True and Measured Values.

Decision	Relationship Between True and Measured Values	Assumptions
Not applicable. Only analytical laboratory data will be used for site closeout decisions.		

A cost function is then developed that relates the number of samples to the total cost of sampling and analysis. The cost functions developed here will be used in the next step as part of the trade-off analyses that will be performed to determine the optimal number of samples. The costs that should be considered include, but are not limited to, mobilization, sample collection, and sample analysis costs.

Table 7-7 includes the calculation of the number of samples for each design alternative. Using the equations outlined in DQO Step 3, the number of samples for each design alternative is calculated. The Type I and Type II error rates (and other inputs in the equations) are varied to examine the relationship between the number of samples and the inputs.

Sample sizes will be calculated after field screening data provide estimates of the population variances for the COCs. With these estimates of the variances, it is inappropriate to calculate the number of samples needed for closeout.

Table 7-7. Calculation of Theoretical Number of Samples for Each Design Alternative.

Estimated standard deviation = Range/6 Lower bound of gray region = 80% of action level			
	$\beta = 0.10$	$\beta = 0.20$	$\beta = 0.25$
$\alpha = 0.01$	---	---	---
$\alpha = 0.05$	---	---	---
$\alpha = 0.10$	---	---	---

$$n_d = \sigma^2 \left\{ \frac{z_{1-\beta} + z_{1-\alpha}}{C_s - \mu_1} \right\}^2 + \frac{1}{2}(z_{1-\alpha})^2$$

Equation taken from *Guidance for the Data Quality Objectives Process*, EPA QA/G-4 (EPA 1994b), where:

σ	=	the standard deviation.
$Z_{1-\alpha}$ and $Z_{1-\beta}$	=	the critical values for the normal distribution with probabilities of $1-\alpha$ and $1-\beta$, respectively.
C_s	=	the cleanup standard, which will be the limit in Table 5-3.
μ_1	=	the true mean concentration (less than the cleanup standard value) where the probability is no greater than 0.20 of deciding the site does not meet the cleanup standard. In other words, μ_1 is the lower bound of the "gray region."

The use of this equation requires that (1) the data are normally distributed, (2) the data are statistically independent (not correlated), (3) that a valid estimate of the variance of the data (σ^2) is available to use in the formula, and (4) the data are obtained by a probability-based sampling design.

Several trade-offs should be considered when determining the optimal number of samples for the given budget. It is important to consider trade-offs so contingency plans can be developed and the added value of selecting one set of considerations over another can be quantified. The results of these trade-off analyses may lead to the re-examination of the DQO outputs developed to this point.

Considerations should include measurement techniques (e.g., field screening, the use of surrogates, and fixed laboratory analysis by more than one method), statistical inputs (varying the width of the gray region or Type I and Type II error rates), and other factors (e.g., spatial and temporal boundaries or scope of the project). Table 7-8 provides the results of the trade-off analysis.

Table 7-8. Results of Trade-Off Analysis.

An estimate of the number of samples needed to characterize each stratum cannot be made at this time. The recommended approach to verification sampling is to collect preliminary screening samples and analyze them using gamma energy analysis. Then, using the equation shown in Table 7-7, calculate the number of verification samples that should be collected. This strategy has worked in past remediation in the 100 Areas.

The design options are then evaluated based on cost and ability to meet the DQO constraints. The results of the trade-off analyses should lead to one of two outcomes: (1) the selection of a design that most efficiently meets all of the DQO constraints, or (2) the modification of one or more outputs from DQO Steps 1 through 6 and the selection of a design that meets the new constraints. Table 7-9 identifies the selection of the appropriate data collection design.

Table 7-9. Selection of Appropriate Data Collection Design.

Decision	Type of Design	Optimum Number of Samples
1 and 5	Judgmental	Based on professional judgment.
2	Statistical	Sample number calculated based variance of limited field investigation (Appendix B, DOE-RL [1998a]).
3 and 4	Statistical	Actual sample number calculated based on stratum-specific variance developed from field screening data.
6	Judgmental	One sample collected from each end of the pipeline.
7	Systematic	12 samples.

An outline of alternative strategies is presented in Table 7-10.

Table 7-10. Outline of Alternative Strategies.

Decision	Alternative
3 and 4	If the analytical results are not sufficient to demonstrate that cleanup levels are met based on sample design, a combination of statistical analysis, professional judgment, and balancing factors (agreed to by the regulators) will be used to determine if the site should be further excavated.

Table 7-11 lists the key features of the selected design.

Table 7-11. Key Features of Selected Design.

Decisions 2, 3, and 4	Strata of interest should be randomly sampled.

Table 7-12 documents the theoretical assumption.

Table 7-12. Documentation on Theoretical Assumptions.

Decision 2	Assumes that data are lognormally distributed, as documented in DOE-RL (1998a).
Decisions 3, 4, and 7	No assumptions have been made regarding the data. Distribution of data will be determined based on field screening data.

8.0 REFERENCES

40 CFR 141, "National Primary Drinking Water Regulations," *Code of Federal Regulations*, as amended.

40 CFR 196, "Radiation Site Cleanup Regulation," *Code of Federal Regulations*, as amended.

40 CFR 261, "Identification and Listing of Hazardous Waste," *Code of Federal Regulations*, as amended.

ANL, 1993, *Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD*, Version 5.91, ANL/EAD/LED-2, Working Draft for Comment, Argonne National Laboratory, Argonne, Illinois.

BHI, 1995a, *Qualitative Risk Assessment for the 100-NR-1 Source Operable Unit*, BHI-00054, Rev. 1, Bechtel Hanford, Inc., Richland, Washington.

BHI, 1995b, *Qualitative Risk Assessment for the 100-NR-2 Operable Unit*, BHI-00055, Rev. 1, Bechtel Hanford, Inc., Richland, Washington.

BHI, 1996, *Data Quality Objectives Workshop Results for 1301-N and 1325-N Characterization*, BHI-00368, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

BHI, 1998a, *Environmental Restoration Disposal Facility Waste Acceptance Criteria*, BHI-00139, Rev. 3, Bechtel Hanford, Inc., Richland, Washington.

BHI, 1998b, *Field Investigation Plan for 1301-N and 1325-N Facilities Sampling to Support Remedial Design*, BHI-01236, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

BHI, 1999a, *100-NR-1 Design Project Data Quality Objective; Decision-Maker Interviews*, CCN 069715, ERC Meeting Minutes dated June 18, 1999, Bechtel Hanford, Inc., Richland, Washington.

BHI, 1999b, *100-NR-1 Treatment, Storage, and Disposal Units Engineering Study*, BHI-01092, Rev. 1, Bechtel Hanford, Inc., Richland, Washington.

BHI, 1999c, *Data Summary Report for 116-N-1 and 116-N-3 Facility Soil Sampling to Support Remedial Design*, BHI-01271, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), 42 U.S.C 9601, et seq.

DOE, 1999, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, DOE/EIS-0222F, U.S. Department of Energy, Washington, D.C.

DOE-RL, 1996, *1301-N and 1325-N Liquid Waste Disposal Facilities Limited Field Investigation Report*, DOE/RL-96-11, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1998a, *100-NR-1 Treatment, Storage, and Disposal Units Corrective Measures Study/Closure Plan*, DOE/RL-96-39, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1998b, *Proposed Plan for Interim Remedial Action and Dangerous Waste Modified Closure of the Treatment, Storage, and Disposal Units and Associated Sites in the 100-NR-1 Operable Unit*, DOE/RL-97-30, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, 1993, *Statistical Guidance for Ecology Site Managers*, Supplement S-6, "Analyzing Site or Background Data with Below-Detection Limit or Below-PQL Values (Censored Data Sets)," Washington State Department of Ecology, Toxics Cleanup Program, Olympia, Washington.

Ecology, 1995, *Guidance on Sampling and Data Analysis Methods,* 94-49, Washington State Department of Ecology, Toxics Cleanup Program, Olympia, Washington.

Ecology, EPA, and DOE, 2000, *Interim Remedial Action Record of Decision (ROD) Declaration, USDOE Hanford 100 Area 100-NR-1 Operable Unit, Hanford Site*, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

EPA, 1989, *Methods for Evaluating the Attainment of Cleanup Standards, Volume 1: Soils and Solid Media*, EPA 230/2-89/042, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1994a, *Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children*, EPA 540/R-93/081, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1994b, *Guidance for the Data Quality Objectives Process*, EPA QA/G-4, EPA/600/R-96/055, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.

NBS, 1963, *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air or Water for Occupational Exposure*, NBS Handbook 69, as amended, U.S. Department of Commerce, Washington, D.C.

Resource Conservation and Recovery Act of 1976 (RCRA), 42 U.S.C. 6901, et seq.

WAC 173-201, "Water Quality Standards for Surface Waters of the State of Washington," *Washington Administrative Code*, as amended.

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.

WAC 173-340, "Model Toxics Control Act – Cleanup," *Washington Administrative Code*, as amended.

WAC 246-290, "Public Water Supplies," *Washington Administrative Code*, as amended.

WHC, 1994, *100-N Area Technical Baseline Report*, WHC-SD-EN-TI-251, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A

ISOTOPIC RELATIONSHIPS IN THE 100 NR-1 OPERABLE UNIT WASTE STREAM

DISCLAIMER FOR CALCULATIONS

The calculations that are provided in this appendix are included for reference only. Use of these calculations by persons who do not have access to all of their pertinent factors could lead to incorrect conclusions or assumptions.

Before applying these calculations to work activities or projects outside the context of this report, these calculations must be thoroughly reviewed with appropriate and authorized Hanford Site ERC personnel. Without this review, the ER Project cannot assume any responsibility for the use of these calculations.

THIS PAGE INTENTIONALLY
LEFT BLANK

CALCULATION COVER SHEET

Project Title: Remedial Action/Waste Disposal **Job No.** 22192
Area: 100 NR-1 Operable Unit
Discipline: Environmental Engineering ***Calc. No:** 0100N-CA-V0019
Subject: Isotopic Relationships in the 100 NR-1 Operable Unit Waste Stream
Computer Program: N/A **Program No.** N/A

Committed Calculation ☑ **Preliminary** ☐ **Superseded** ☐

Rev.	Sheet Numbers	Originator	Checker	Reviewer	Approval	Date
00	10	S. K. De Mers	J. C. Wiles	S. L. Winslow	A. R. Michael	1/3/2000

SUMMARY OF REVISION

Scanned:	Rev.	Date	Bar Code No.	Rev.	Date	Bar Code No.

*Obtain Calc. No. from DIS.

CALCULATION SHEET

Originator: S. K. De Mers **Date:** 12/28/99 **Calc. No.** 0100N-CA-V0019 **Rev. No.** 00
Project: Remedial Action & Waste Disposal **Job No.** 22192 **Chk:** **Date:** 12/28/99
Subject: Isotopic Relationships in the 100 NR-1 Operable Unit Waste Stream **Sheet No.** 1 of 9

The Remedial Action/Waste Disposal Project (RAWD) will be remediating waste sites in the 100 NR-1 Operable Unit. These waste sites present a unique challenge to current remedial action practices in that the residual radioactive material in the waste site will cause high background radiation. This will make it difficult to provide real time analysis of the waste unless the radioactivity from that waste can be tied to the dose rates detected in the waste. This calculation is to estimate that relationship for each milli-roentgen (mR) of gamma radiation detected.

Assumptions:

1) The principal source of gamma radiation is from the decay of ^{60}Co and ^{137}Cs (^{137m}Ba).

2) The data obtained from Table 5-6 & 5-8 of BHI-01271, *Data Summary Report for the 116 N-1 and 116 N-3 Facility Soil Sampling to Support Remedial Design*, can be used to developed the relationship of the isotopes present.

3) The relationships of isotopes that are contained in the reactor's fuel can be estimated based on Table C-17, *Selected Radionuclides in Burned Hanford Site Fuel After 40-Year Decay,* of DOE/RL-95-34, *118 B-1 Burial Ground Excavation Treatability Test Report*. The relationships in this table will have to be altered to a 12-year vice a 40-year decay.

4) "N" reactor last operated on January 7 1987 and the sampling done in Assumption #1 was done in December 1998. Therefore, the decay and ingrowth time is set at 12 years.

5) Hard to detect isotopes such as ^{241}Pu can be determined based on the detectable activity of a parent or daughter isotope.

6) ^{240}Pu activity can be combined with ^{239}Pu activity as the energies of the alpha particles emitted from both isotopes is very similar and difficult to tell apart in laboratory analysis. Most laboratories report the activities of these isotopes as $^{239/240}$Pu.

7) The activity of ^{60}Co and ^{137}Cs (^{137m}Ba) can be combined as "equivalent" ^{60}Co activity for dose rates.

8) MICROSHIELD Ver. 5.03 and RADECAY Ver. 3.01 may be used in the establishment of dose rates and isotopic relationships.

9) All sources of radioactivity within the waste stream originated in the reactor and production was stopped, other than ingrowth from decay, when the reactor was shutdown.

10) The dose rate at one foot from any source can be determined using the formula 6CNE, where C is the curies present, N is the number/abundance of the gamma ray/s and E is the energy of the gammas.

CALCULATION SHEET

Originator: S. K. De Mers	**Date:** 12/28/99	**Calc. No.** 0100N-CA-V0019	**Rev. No.** 00
Project: Remedial Action & Waste Disposal	**Job No.** 22192	**Chk:**	**Date:** 12/28/99
Subject: Isotopic Relationships in the 100 NR-1 Operable Unit Waste Stream			**Sheet No.** 2 of 9

To establish the relationships of the various isotopes in the 100 NR-1 waste stream and relate them to a dose rate, the first step is to establish the isotopes, which will significantly contribute to the gamma dose rate.

There are several isotopes in the waste stream that would contribute to the gamma dose rate. They are ^{60}Co, ^{137}Cs (^{137m}Ba), ^{154}Eu, ^{155}Eu and ^{241}Am. However, because ^{154}Eu, ^{155}Eu and ^{241}Am have concentrations about two orders of magnitude below those of ^{60}Co and ^{137}Cs (^{137m}Ba), they will be considered insignificant in their gamma dose rate contribution. A comparison of the energies and abundance of the gammas emitted from ^{60}Co and ^{137}Cs (^{137m}Ba) shows the contribution of the gamma ray from ^{137}Cs (^{137m}Ba) to be about 23.7% of the gamma ray energy from ^{60}Co. Using the formula 6CNE, where C is the curies present, N is the number/abundance of the gamma ray/s and E is the energy of the gammas, we show the following relationship. For comparison purposes, C is one curie and is used for each isotope.

$$6CNE = Dose\ Rate\ in\ R/hr\ at\ 1\ foot$$

$$6CNE\ (Ba137m) = 6 * 1\ Curie * Photon\ Abundance\ (0.8998) * Energy\ (0.66165\ MEV) = 3.57\ REM\ at\ 1\ foot$$

$$6CNE\ (Co60) = 6 * 1\ Curie * Photon\ Abundance\ (2) * Energy\ (\frac{1.1732 + 1.3325}{2})\ MEV = 15.03\ REM\ at\ 1\ foot$$

$$\frac{3.57\ REM}{15.03\ REM} = 0.237$$

From this, we can use the factor 0.237, to multiply times the ^{137}Cs (^{137m}Ba) activity to determine its equivalent activity to that of ^{60}Co. Adding these two contributions together (the activity of ^{60}Co and the activity of ^{137}Cs (^{137m}Ba) times 0.237), will give the total expected dose rate based on equivalent ^{60}Co activity.

This relationship is shown in the table on the next page for ^{137}Cs (^{137m}Ba) and ^{60}Co and their combined dose rates for the 116 N-3 waste stream. The values listed for Cs137 in the lower table have a correction factor applied of 0.237 to equate their activity to Co60.

The top portion of the table lists the activities for the major gamma emitting isotopes for RCF and for TMA. They also include the actual dose rates, and a dose rate from a MICHROSHIELD model using the actual weights and activities. Attachment 1 shows a typical model for the TMA sample #BOTBY0.

This was done for comparison purposes. The results are listed in the last line of the bottom table where the average equivalent Co60 activity is listed that would yield one milli-rem per hour of dose rate. The actual dose rates listed are the ones measured in the field, 1 cm from the sample containers.

Using all values for estimating activity, 2,720 pCi/gm equivalent ^{60}Co would be used to roughly equate to a 1.0 mR/hr dose rate from a large sample volume (trackhoe bucket).

CALCULATION SHEET

Originator: S. K. De Mers	**Date:** 12/28/99	**Calc. No.** 0100N-CA-V0019	**Rev. No.** 00
Project: Remedial Action & Waste Disposal	**Job No.** 22192	**Chk:**	**Date:** 12/28/99
Subject: Isotopic Relationships in the 100 NR-1 Operable Unit Waste Stream			**Sheet No.** 3 of 9

116 N-3 Test Pit Data

2.0-3.5 feet

RCF
HEIS# BOTC10
RCF # 5077, Sample Volume = 20 ml

Isotope	*Activity* pCi/gm	*Model Dose Rate* mR/hr	*Actual Dose Rate* mR/hr
Cs137	1.60E+04		

TMA
HEIS # BOTBY0
TMA # N901012-01, Sample Volume = 120 ml

Isotope	*Activity*	*Model Dose Rate*	*Actual Dose Rate*
Co60	2.58E+04	6.2	8
Cs137	8.39E+03		

3.5-4.5 feet

RCF
HEIS# BOTC11
RCF # 5078, Sample Volume = 20 ml

Isotope	*Activity* pCi/gm	*Model Dose Rate* mR/hr	*Actual Dose Rate* mR/hr
Cs137	5.60E+03		

TMA
HEIS # BOTBY1
TMA # N901012-02, Sample Volume = 120 ml

Isotope	*Activity*	*Model Dose Rate*	*Actual Dose Rate*
Co60	5.07E+03	1.3	2
Cs137	3.08E+03		

4.5-6.0 feet

RCF
HEIS# BOTC12
RCF # 5079, Sample Volume = 20 ml

Isotope	*Activity* pCi/gm	*Model Dose Rate* mR/hr	*Actual Dose Rate* mR/hr
Cs137	6.80E+03		

TMA
HEIS # BOTBY2
TMA # N901012-03, Sample Volume = 120 ml

Isotope	*Activity*	*Model Dose Rate*	*Actual Dose Rate*
Co60	7.24E+03	1.9	3
Cs137	4.39E+03		

Co60	Cs137	pCi/mr	mr/hr
5.30E+04	3.79E+03	2.84E+03	20
1.60E+04	1.33E+03	3.77E+03	4.6
9.00E+03	1.61E+03	1.54E+03	6.9
2.60E+04	2.24E+03	2.71E+03	10.5

Co60	Cs137	pCi/mr	mr/hr
2.58E+04	1.99E+03	3.16E+03	8
5.07E+03	7.30E+02	2.42E+03	2
7.24E+03	1.04E+03	2.59E+03	3
1.27E+04	1.25E+03	2.72E+03	4

CALCULATION SHEET

Originator: S. K. De Mers Date: 12/28/99 Calc. No. 0100N-CA-V0019 Rev. No. 00
Project: Remedial Action & Waste Disposal Job No. 22192 Chk: Date: 12/28/99
Subject: Isotopic Relationships in the 100 NR-1 Operable Unit Waste Stream Sheet No. 4 of 9

$^{239/240}$Pu

To establish the relationship between the equivalent ^{60}Co and the $^{239/240}$Pu present, sample data was used. The average sample activity for $^{239/240}$Pu from the test pit data, Table 5-8 of BHI-01271, *Data Summary Report for the 116 N-1 and 116 N-3 Facility Soil Sampling to Support Remedial Design* shows the levels of 46.4, 11.2 and 13.3 pCi/gm per mR/hr for an average of 23.6 pCi/gm per mR/hr. From the same data, ^{241}Am showed 25.7, 5.58 and 6.56 pCi/gm per mR/hr for an average of 12.6 pCi/gm per mR/hr.

To relate the hard to determine isotopes, the following relationships are provided.

^{241}Pu

^{241}Pu gives off a low energy beta and can only be determined using exotic and expensive laboratory techniques. Its daughter product, ^{241}Am, can be easily detected in a laboratory either by a Gamma Energy Analysis (GEA) or by an Alpha Energy Analysis (AEA). Therefore if a relationship between ^{241}Pu and ^{241}Am can be estimated then no special laboratory analysis need be performed. To determine this relationship, one curie of ^{241}Pu is decayed for 12 years, the time between the reactor shutdown and the sampling done in December 1998. Using the RADECAY model, the decayed results show the ^{241}Pu activity would have decayed to 0.56123 curies. The build up of ^{241}Am would be 0.014465 curies. Dividing these two numbers together would yield a conservative ratio of ^{241}Pu to ^{241}Am.

$$\frac{0.56123\ curies\ Pu241}{0.014465\ curies\ Am241} = 38.8$$

Therefore, to determine the activity of ^{241}Pu, multiply the ^{241}Am activity by 38.8. This is a conservative approach as the more time that passes, the smaller this multiplier becomes. For example, after a 40-year decay, the multiplier would be 5.34 versus 38.8.

Other Isotopes

Other isotopes that have been detected or postulated in 100 area waste streams need to be addressed.

^{233}U

^{233}U is created by the decay of ^{233}Th, also an isotope with a short half-life (22.3 minutes). ^{233}Th is created when ^{232}Th is bombarded with neutrons. Although not normally used in Hanford reactors, some effort was made to create ^{233}U using ^{232}Th targets and therefore cannot be discounted. Like ^{240}Pu, ^{233}U is hard to distinguish between it and ^{234}U. Therefore, the activities of both will be reported together as $^{233/234}$U.

CALCULATION SHEET

Originator: S. K. De Mers	**Date:** 12/28/99	**Calc. No.** 0100N-CA-V0019	**Rev. No.** 00
Project: Remedial Action & Waste Disposal	**Job No.** 22192	**Chk:**	**Date:** 12/28/99
Subject: Isotopic Relationships in the 100 NR-1 Operable Unit Waste Stream			**Sheet No.** 5 of 9

^{237}Np

^{237}Np is developed in the reactor waste stream by the decay of ^{237}U and by the decay of ^{241}Am. The decay from ^{241}Am is easy to establish as we know how much ^{241}Am is present and the program RADECAY can determine the relationship between ^{241}Am and ^{237}Np. Decaying 1 pCi of ^{241}Am for 12 years shows there are 3.85E-7 pCi's of ^{237}Np for 1 pCi of ^{241}Am. This is not a significant source of ^{237}Np.

The contribution to ^{237}Np from the decay of ^{237}U is harder to determine as we do not know how much ^{237}U was created in the reactor that then decayed to ^{237}Np. ^{237}Np is relatively easy to detect and the waste profile for this waste stream lists 22 pCi/gm as its highest known value. This will be assumed to be the value when a dose rate of 1.0 mR/hr is detected and then scaled up from there as the dose rate changes.

^{242m}Am & ^{234}Am

^{242m}Am & ^{234}Am are produced in the reactor by adding neutrons to Am241 and/or by the decay of ^{243}Pu. There currently is too little information on how to develop a relationship between ^{242m}Am & ^{234}Am and ^{241}Am. Therefore to conservatively predict the levels of ^{242m}Am & ^{234}Am, it will be assumed that the mass of ^{242m}Am & ^{234}Am, will be the same mass as that of ^{241}Am. The activity of ^{241}Am when the dose rate is 1 mR/hr has been determined to be 12.6 pCi/gm. The mass of ^{241}Am, as determined by its activity, for this dose rate is 3.67 E-12 gms. When this value is applied to ^{242m}Am, the activity is 36 pCi/gm and when applied to ^{243}Am the activity is 0.74 pCi/gm.

^{238}Pu

^{238}Pu may be detected by laboratory analysis via an AEA. However, based on the data in the C-17 table listed in Assumption #3, and reverse decaying the value for 12 years instead of 40 years, a multiplier of 0.06 can be used. This factor is multiplied by the ^{239}Pu activity to come up with the ^{238}Pu activity.

CALCULATION SHEET

Originator: S. K. De Mers	Date: 12/28/99	Calc. No. 0100N-CA-V0019	Rev. No. 00
Project: Remedial Action & Waste Disposal	Job No. 22192	Chk:	Date: 12/28/99
Subject: Isotopic Relationships in the 100 NR-1 Operable Unit Waste Stream			Sheet No. 6 of 9

^{244}Pu

^{244}Pu is created in the reactor by adding neutrons in a series from ^{239}Pu. ^{244}Pu may be detected by measuring the gamma energies of one of its daughter products, ^{240m}Np as it would be in secular equilibrium with ^{244}Pu after twelve years of decay. However, the activity would have to be high enough to be detectable by a gamma energy analysis. Without any other data available, the level of ^{244}Pu has to be determined from neutron activation as follows:

1) The fuel was left in the reactor long enough that there was about a 10% in-growth of ^{240}Pu after the development of the desired product, ^{239}Pu. The measured activities of the ^{239}Pu and ^{241}Am show this to be a fair approximation when their activities are converted to mass.

2) The 10% conversion by mass continues from ^{240}Pu all the way to ^{244}Pu. When complete and when correcting the mass change for known activity, the mass of ^{244}Pu when the ^{239}Pu activity is 23.6 pCi/gm is 4.65 E-15 gms. Converting this to an activity of ^{244}Pu gives a value of 9.24E-08 pCi/gm.

^{243}Cm, ^{244}Cm, ^{245}Cm, ^{246}Cm, ^{247}Cm & ^{248}Cm

^{243}Cm, ^{244}Cm, ^{245}Cm, ^{246}Cm, ^{247}Cm & ^{248}Cm are postulated to exist in the waste stream, but detecting them is difficult and expensive. The values to be used for each mR/hr for the Curium chain, are the ones listed in the waste profile with the exception of ^{244}Cm which has been detected by the radiological counting facility. When using the methods of detected concentrations to dose rates from samples, the detected ^{244}Cm shows a value of 0.55 pCi/gm for each mR/hr. Sample data: sample #BOTC18 with 5.1 pCi/gm ^{244}Cm, sample # BOTC19 with 33 pCi/gm ^{244}Cm, sample BOTC20 with 6.1 pCi/gm and sample # BOTC21 with 460 pCi/gm ^{244}Cm. The dose rates on these samples were 60, 80, 100 and 400 mR/hr respectively.

^{99}Tc, ^{234}U, ^{235}U & ^{238}U

^{234}U, ^{235}U & ^{238}U can be determined in the same way as ^{238}Pu. The table listed above shows a relationship of 0.007 curies of ^{99}Tc, ^{234}U and ^{238}U for each curie of ^{239}Pu. For ^{235}U, it lists a relationship of 0.0003 curies of ^{235}U for each curie of ^{239}Pu. Do to the long half-lives involved, no compensation for decay was done.

^{3}H, ^{63}Ni ^{14}C & ^{59}Ni

^{3}H, ^{63}Ni ^{14}C & ^{59}Ni are also difficult to detect isotopes. Table C-17 list relationships for these isotopes are well. The table lists a factor of 0.17 curies of ^{3}H for each curie of ^{239}Pu. Compensating for decay, the factor is corrected to 0.819. For ^{63}Ni, the table lists a factor of 0.03, compensating for decay it becomes 0.0367. For ^{14}C and ^{59}Ni, the factors listed in the table (0.002-^{14}C and 0.0003-^{59}Ni) are used as they, like Uranium have a long half-lives.

CALCULATION SHEET

Originator:	S. K. De Mers	Date: 12/28/99	Calc. No. 0100N-CA-V0019		Rev. No. 00
Project:	Remedial Action & Waste Disposal	Job No. 22192	Chk:		Date: 12/28/99
Subject:	Isotopic Relationships in the 100 NR-1 Operable Unit Waste Stream				Sheet No. 7 of 9

^{90}Sr, ^{154}Eu & ^{155}Eu

^{154}Eu & ^{155}Eu have all been detected in the waste stream and their ratios to the equivalent ^{60}Co value is determined based on their detected value compared to the same value for the equivalent ^{60}Co for the same sample. The only sample data showing values for europium is the analysis performed at the radiological counting facility for samples taken from the 116 N-3 crib. There are only two sample results for ^{154}Eu and only one result for ^{155}Eu. The sample activity is dividing by the dose rate from the sample to give a ratio of pCi/gm to mR/hr. Sample #BOTC18 had 1,900 pCi/gm ^{154}Eu and the sample had a dose rate of 60 mR/hr. Sample # BOTC21 had an activity of 43,000 pCi/gm ^{154}Eu and 8,000 pCi/gm ^{155}Eu and this sample read 400 mR/hr. To start we will only use the data from the second sample. Therefore, for ^{154}Eu, a ratio of 107.5 pCi/gm per mR/hr is established and for ^{155}Eu a ratio of 20 pCi/gm per mR/hr is established.

For ^{90}Sr, values were detected in three samples from the trench and can be compared to the dose rate to find a ratio to equivalent ^{60}Co. Only the trench data is used, as the dose rates taken are for the samples themselves when prepared for shipment. The dose rates for the crib samples when prepared for shipment are not available. The samples are: BOTBY0, which had 853 pCi/gm ^{90}Sr; BOTBY1, which had 371 pCi/gm ^{90}Sr and BOTBY2, which had 408 pCi/gm ^{90}Sr. These samples read 8.8, 2.4 and 3.2 mR/hr respectively. This gives an average value of 126 pCi/gm for each mR/hr.

CALCULATION SHEET

Originator: S. K. De Mers	Date: 12/28/99	Calc. No. 0100N-CA-V0019	Rev. No. 00
Project: Remedial Action & Waste Disposal	Job No. 22192	Chk:	Date: 12/28/99
Subject: Isotopic Relationships in the 100 NR-1 Operable Unit Waste Stream			Sheet No. 8 of 9

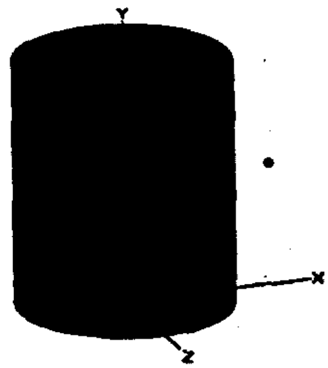
Attachment 1 MICROSHILED RUN

MicroShield v5.03 (5.03-00002)
Bechtel Hanford, Inc.

Page : 1
DOS File: BOTBY0.MS5
Run Date: December 28, 1999
Run Time: 7:12:05 AM
Duration: 00:00:05

File Ref: N/A
Date:
By:
Checked:

Case Title: Case 1
Description: Case 1
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions

Height	6.0 cm	2.4 in
Radius	2.5 cm	1.0 in

Dose Points

	X	Y	Z
# 1	3.5 cm	3 cm	0 cm
	1.4 in	1.2 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	117.81 cm³	Concrete	1.9
Transition		Air	0.00122
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	1.7763e-006	6.5722e+004	1.5077e-002	5.5786e+002
Co-60	5.7688e-006	2.1345e+005	4.8967e-002	1.8118e+003
Cs-137	1.8777e-006	6.9473e+004	1.5938e-002	5.8971e+002

Buildup
The material reference is : Transition

Integration Parameters

Radial	10
Circumferential	10
Y Direction (axial)	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	1.361e+03	4.372e-02	9.988e-02	3.642e-04	8.320e-04
0.0322	2.510e+03	8.393e-02	1.949e-01	6.755e-04	1.568e-03
0.0364	9.135e+02	4.549e-02	1.242e-01	2.585e-04	7.059e-04
0.6616	5.914e+04	1.928e+02	2.422e+02	3.739e-01	4.695e-01
0.6938	3.482e+01	1.197e-01	1.491e-01	2.311e-04	2.879e-04
1.1732	2.134e+05	1.312e+03	1.528e+03	2.344e+00	2.730e+00
1.3325	2.134e+05	1.508e+03	1.733e+03	2.617e+00	3.007e+00
TOTALS:	4.908e+05	3.013e+03	3.504e+03	5.336e+00	6.210e+00

CALCULATION SHEET

Originator:	S. K. De Mers	**Date:** 12/28/99	**Calc. No.** 0100N-CA-V0019	**Rev. No.** 00	
Project:	Remedial Action & Waste Disposal	**Job No.** 22192	**Chk:**	**Date:** 12/28/99	
Subject:	Isotopic Relationships in the 100 NR-1 Operable Unit Waste Stream			**Sheet No.** 9 of 9	

Attachment 2 – Decay Chain

	Rx Fuel				
					Pa233
				^	α 1 to 1
	Th231		Th232		Np237
^	α 1 to 1	^	α ε–9	^	β 100%
	U235	***>n***	***U236***	***>n***	***U237***

Isotopes highlighted in bold are the main stream created by neutron activation.
The 1 to 1 term means the parent and daughter are in secular equilibrium
Arrows either ^ or > indicate the direction of decay or activation.
Where no arrow is indicated, the direction of decay is down.
Next to the method of decay is a number indicating the ratio of the parent to the daughter.
If a % is listed then the parent has completely converted to the daughter/s.

				Rx Targets				U234		U235		U236		Am241		U238		Am243		U240
							^	α ε–4	^	α ε–8	^	α ε–6	^	β 0.026	^	α 2ε–9	^	β 100%	^	β 1 to 1
								Pu238		Pu239		Pu240		Pu241		Pu242		Pu243		Pu244
							^	α 0.005	^	α 4ε–4	^	α 1.6ε–3	^	α 0.44	^	α 2ε–5	^	α 1 to 1	^	α 9ε–8
		Th231		Th232		Np237		***Cm242***	***>n***	***Cm243***	***>n***	***Cm244***	***>n***	***Cm245***	***>n***	***Cm246***	***>n***	***Cm247***	***>n***	***Cm248***
	^	α ε–7	^	α ε–9	^	α ε–6	^	***β 83%***		ε 3ε–6										
		U235		U236		***Am241***	***>n***	***Am242***	>n	Am243		U240								
	^	α ε–8	^	α ε–6	^	***β .026***	^	ε 17%	^	β 100%	^	β 1 to 1								
		Pu239	***>n***	***Pu240***	***>n***	***Pu241***	>n	Pu242	>n	Pu243	>n	Pu244								
	^	***β 100%***	^	β 100%				α 2ε–9												
		Np239		Np240m				U238												
	^	***β 100%***	^	β 100%																
U238	***>n***	***U239***	>n	U240																

DISTRIBUTION

ERC Team

A. Antipas, CH2M Hill/SEA	
K. E. Cook, CHI	H9-02
F. M. Corpuz, BHI	X9-06
R. L. Donahoe, BHI	H0-17
L. A. Durfee, CHI (Project File)	H9-01
J. D. Fancher, CHI	H9-02
K. R. Fecht, BHI	H0-02
C. W. Hedel, CHI	H9-03
J. D. Ludowise, CHI (5)	H9-03
E. K. Mokuiki, BHI	H9-03
R. W. Ovink, CHI	H9-03
W. H. Price, BHI	H0-18
Document and Information Services (3)	H0-09
DOE-RL Public Reading Room	H2-53
Hanford Technical Library	P8-55